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The Influence of Various Physiological Responses on Ratings of Perceived Exertion Before and After Training.

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THE INFLUENCE OF VARIOUS PHYSIOLOGICAL RESPONSES ON RATINGS OF PERCEIVED EXERTION BEFORE AND AFTER TRAINING

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Health, Physical,

and Recreation Education

by
David R. Carter
B.S., Lamar University, 1973
M.S., Lamar University, 1974
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ABSTRACT

The influence of certain physiological responses on Ratings of Perceived Exertion (RPE) at specific points in an exercise bout were investigated in conjunction with the influence of bicycle training on the RPE. Twelve male college subjects were randomly selected from beginning weight training courses. Mean physical characterisics for subjects were age, 20.43 ($\pm$ 2.58) years; height, 100.02 ($\pm$ 9.01) cm; and weight, 74.59 ($\pm$ 7.63) kg.

Subjects (N = 12) were administered a Physical Work Capacity test (PWC_{180}) in order to establish a work load criterion (HR = 180 bpm) for the 6 min. RPE test protocol utilizing a 60 rpm cadence on the bicycle ergometer. Heart rate (HR), oxygen consumption (VO_2 l/min., VO_2 ml/kg/min.), and carbon dioxide production (VCO_2 l/min., VCO_2 ml/kg/min.) data were recorded at each 30 sec. interval in the 6 min. exercise bout. Respiratory quotient (RQ) and oxygen pulse (OXP) were computed from the metabolic data. Two minutes after completion of the 6 min. work bout, a 6 cc blood sample was drawn from the anticubital vein for the determination of blood lactate (LA), sodium (Na), and potassium (K^+) concentration.

After completion of the pre test an individualized bicycle training program was designed. Training consisted of pedalling on the bicycle ergometer 10 min./day, 3 days/week for 5 weeks. Work loads by weeks were based on percentages of the PWC_{180} estimate (i.e. 80% PWC_{180} for week 1 to 120% PWC_{180} for week 5). Upon completion of the

training phase a post test evaluation was administered utilizing the same protocol as established for the pre test.

Split plot analysis of variance, factorial analysis of variance, and stepwise multiple regressions were utilized to determine differences occuring as a result of training and the importance of the physiological variables in predicting the RPE. Split plot analysis revealed that HR, RPE, and RQ significantly decreased as a result of training. Oxygen consumption (VO_2 l/min., VO_2 ml/kg/min.), VCO_2 l/min., VCO_2 ml/kg/min., and OXP were significantly increased as a result of training.

Factorial analysis revealed significant decreases in LA and Na concentrations. No significant changes in K^+ concentration were revealed.

Stepwise regression models (N = 4) for two, 3 min. time periods within each 6 min. bout accounted for 45 to 68 percent of the variance for predicting the RPE. Pre test regressions appeared to be better predictors of the RPE than post test regressions. Therefore, training appeared to alter the predictive ability of the physiological factors responsible for lowering the RPE for the post test. Thus, RPE appears to be a multifaceted and multistructural composite of physiological and perhaps psychological phenomena.

CHAPTER I

INTRODUCTION

Man is regarded as a psycho-somatic unit in which all psychological events have corresponding physiological responses (Borg, 1973). Because of the psycho-somatic nature of human performance, research has drawn upon a number of disciplines in order to evaluate responses to various stimulus situations.

Borg and Noble (1974) advocated that success in physical performance depends on (1) physiological and morphological endowments and (2) psychological resources including the information and decision making processes. Information and decision making processes involved in physical performance rely heavily on perceptual cues. Such perceptual cues allow an individual to regulate work intensity so as to satisfy the specific goals and requirements of the activity.

Gunnar A. V. Borg (1962, 1973) developed a 21 point graded scale which made possible direct individual comparisons of the perception of exertion. At every second number on the scale, a corresponding verbal expression was placed, such as 3 = "very, very light" and 19 = "very, very laborious." The scale was found to be functional and correlations of .80 to .90 were found with heart rates of subjects tested on a bicycle ergometer. The original scale was later changed to a 15 point graded category scale with numeric values ranging from 6 to 20 in order to match the variations in heart rate from 60 to 200 bpm. The scale was based on the knowledge that heart rate increases linearly in relation to work load on a bicycle ergometer (Borg, 1973). The new scale, which is called the Ratings of Perceived Exertion Scale (RPE-Scale) or "Borg Scale" has been used extensively throughout the world (Borg & Noble, 1974).

In an effort to explain how exertion is perceived, researchers have studied various physiological and psychological components. Many of the researchers have concluded that the overall perception of exertion represents a Gestalt or an integration of various sensations and feelings (Borg, 1962; Borg & Noble, 1974; Ekblom & Goldborg, 1971; Henriksson, Knuttgen & Bonde-Peterson, 1972; Noble, Metz, Pandolf, Bell, Cafarelli & Sime, 1973a; Noble, Metz, Pandolf & Cafarelli, 1973b; Pandolf, 1972; Pandolf, Burse & Goldman, 1975; Pandolf & Noble, 1973). Sensations from the muscles, skin, joints and circulatory and respiratory feedback all appear to influence the perception of exertion (Borg, 1962; Pandolf et al., 1973). Because the various areas of the body appear to contribute differently to the perception of exertion, Ekblom and Goldborg (1971) proposed a two factor theory consisting of general fatigue (cardio-respiratory) and local fatigue (muscle). The two factor theory attempted to explain the differences in the RPEs when different modes of exercising were employed. For example, while walking or running, the general cardio-respiratory feedback appeared to dominate the perception of exertion while during cycling the local muscular fatigue dominated. In an effort to identify whether the general or the local feeling of fatigue dominate the perception of exertion, many researchers have isolated specific physiological components known to be associated with exertion and have tried to assess their contribution to the RPE. Physiological variables of heart rate (HR), respiratory rate (RR), oxygen consumption (VO_2), carbon dioxide production (VCO_2), tidal volume, blood flow, blood lactate (LA), sodium (Na), and potassium (K^+) have been explored. Researchers have hypothesized that RPE was influenced differently depending on the intensity of the exercise and the relative importance of the physiological variables at that particular intensity. When the intensity is submaximal, the RPE is influenced primarily from the general or cardiovascular senses, but when maximal or near maximal intensity is utilized the local feeling of exertion appear to dominate. Since workloads of 50% maximum oxygen consumption or greater are normally utilized in RPE testing, the local feelings of exertion would generally be more dominant.

In a study which supports the two factor theory, Allen and Pandolf (1976) found that local factors dominate the perception of exertion during work. They reported that for moderate work (50% VO_2 max) and heavy work (80% VO_2 max) inspired oxygen concentration significantly affected the RPE, and that blood lactate was shown to be the prime cue for RPE. Ekblom and Goldborg (1971), Henriksson et al. (1972), Pandolf and Noble (1973), and Robertson, McCarthy, and Gillespie (1976) also reported that local factors appear to dominate the perception of exertion when compared to an overall feeling of exertion. Even though local factors have been shown to dominate the perception of exertion, it was not clear which physiological components contributed the greatest amount of exertion information for the interpretation of the RPE. Cafarelli and Noble (1975) stated that ventilation was not important for the selection of RPE at low exercise intensities where all cues probably come from working muscle. Oxygen uptake, however, became more important at the upper reaches as indicated by greater differences in RPE.

Very little information has been reported with regard to the effect of training on RPE. However, it is well known that training alters physiological responses. Some of the physiological measures typically studied and their responses to training are as follows: (1) Oxygen consumption (VO_2 l/min. and VO_2 ml/kg/min.) is considered the single most important predictor of aerobic fitness. (2) Respiratory quotient (RQ) predicts the relative contribution of the energy sources being utilized during performance. (3) Oxygen pulse (OXP) is the amount of O_2 which can be delivered to working muscle per heart beat and is considered to be an excellent indicator of aerobic fitness. (4) Sodium (Na) is an electrolyte which helps maintain a balanced condition in body fluids. Marked changes in Na have been linked to fatigue in subjects due to the ionic imbalance in body fluids induced by exercise. (5) Marked disturbances in K+ concentration in body fluids have been linked to muscle fatigue. Within active muscle, K+ concentration has been shown to drop initiating an increase in H+ concentration, thus influencing an increase in the permeability of the cell membrane. Therefore the coupled sodium-potassium pump may be less efficient during muscular activity. (6) Lactic acid builds up during anaerobic glycolysis and tends to inhibit muscle contraction. This build up continues during heavy work and will eventually lead to the cessation of exercise. Perceived exertion cues rely on either general or local sensations arising from physiological alterations, but it is not clear which physiological alterations significantly affect the RPE. Therefore, this study will attempt to investigate and identify the relative influences of certain physiological responses which contribute to the Ratings of Perceived Exertion before and after a training program.

Review of Literature

The literature has been divided into the following categories: (1) development and validation of perceived exertion, (2) training influences on Ratings of Perceived Exertion, (3) psychological influences on Ratings of Perceived Exertion, and (4) physiological influences on Ratings of Perceived Exertion.

Development and Validation of Perceived Exertion

Several studies reported correlation coefficients from .77 to .90 between RPE scores and HR using the Borg Scale (Arstila & Wendelin, 1974; Bar-or, Skinner, Buskirk & Borg, 1972; Borg, 1962, 1970; Borg & Linderholm, 1967; Skinner, Borg & Buskirk, 1970; Ulner, Janz & Lollgen, 1977).

Gamberale (1972) explored the relationship between perceived exertion and HR in physical work, where different muscle groups are involved. The relationship between the RPE and HR was found to be linear. Ulner et al. (1977) reported very high correlation coefficients (*r* = .93) between HR and RPE utilizing 10 subjects, again confirming the results of previous investigations which attempted to establish the validity and reliability of the RPE test.

Arstila and Wendelin (1974) reported high correlation coefficients between RPE scores and HR not only with Borg's 15 point graded category scale (Borg II) (*r* = .87) but also with their own Bars-scale (*r* = .80). Using test-retest to estimate reliability, a correlation coefficient of *r* = .88 was obtained for the Bars-scale and *r* = .94 for the Borg scale. Arstila and Wendelin concluded that both tests resulted in highly linear, repeatable and mutually comparable results. The Borg Scale, however, demonstrated the best performance in many respects, and thus it was suggested to be the preferable test.

Training Influences on Ratings of Perceived Exertion

Fox, McKenzie, and Cohen (1975b) evaluated the metabolic and circulatory responses to submaximal exercise of 15 trained and untrained college males on RPE. Significant decreases were found in VO_2, HR, and LA for the arms and legs with an increased SV. The results indicated that the specificity of training alters various physiological responses and that the control mechanisms responsible for the RPE appeared to be indirectly mediated by skeletal muscles. Therefore, RPE appeared to be primarily influenced by the local factors associated with muscle fatigue. Patton, Morgan, and Vogel (1975) evaluated the effect of the level of physical fitness (cross-sectional) as well as chronic physical training on the perception of exertion (RPE) and concluded that the perception of the intensity of absolute work does not differ according to the level of fitness when studied cross-sectionally, and that significant reductions in perceived exertion occur following training. The two studies suggest that training does alter certain specific physiological responses to exercise to varying degrees depending upon the types of exercise administered. Therefore, it is also reasonable to assume that the physiological responses provide various cues necessary for the individual to evaluate and interpret perception of exertion.

Psychological Influences on Ratings of Perceived Exertion

To assess various psychological attributes, Morgan (1973b) evaluated personality traits, depression traits, anxiety levels, and somatic depression for each volunteer subject through the use of a test battery. A modified version of the Borg scale was used to assess the RPE. He found psychometric variables to interact with the RPE, and recommended that when studying RPE a psychobiological approach be utilized.

Robertson et al. (1975) studied augmenters and reducers while cycling. Augmenters have been found to consistently magnify perceptions of incoming stimuli, whereas reducers tend to decrease what they perceive. The study sought to determine if augmenters consistently assigned higher RPE scores to a given work level than did reducers. No significant differences were found between groups in aerobic fitness and physiological responses. However, between group differences in RPE scores were significant and RPE was found to be significantly higher in the augmenters than in the reducers. Since the responses between groups reduced the likelihood of a physiological cause of RPE differences, sensory augmentation and reduction appears to be more influential on RPE scores at less stressful work loads and became less influential as the stress increased.

Docktor and Sharkey (1971) and Frankenhaeuser, Post, Nordheden, and Sjoeberg (1969) designed studies to determine the effects of catecholamine excretion in the urine, on RPE and various physiological parameters. Docktor and Sharkey (1971) hypothesized that the RPE for a given work load would be decreased due to a reduction in the incoming stimuli (habitation), improved physical fitness, and/or task familiarity. The RPE during the sixth min. and the 150 bpm rating did not significantly change as a result of a five week training period. However, the time to reach 150 bpm increased significantly. Thus, the perception related to HR was the same even though the work load was increased. It was further noted that vanilmandilic acid (VMA) (including adrenaline and noradrenaline) decreased with increased training when HR was held constant. Decreased adrenaline indicated a decrease in the mental stress aspect of the work test while no change in noradrenaline was noted.

<u>Physiological Influences on Ratings of Perceived Exertion</u>

Ekblom and Goldborg (1971) proposed a two factor theory to help explain the variation in RPE during different types of work. The theory includes a local factor controlled by the feelings of strain in the working muscles and a central factor which is comprised primarily of the cardio-pulmonary system. Ekblom and Goldborg (1971) stated that when one of the factors becomes pronounced (psychological or physiological), it appears to dominate the perception of exertion. There is, however, disagreement as to which factors actually influence the perception of exertion under different types of exercise. For example, Kay and Shephard (1969) suggest that the central factor appears to dominate the perception of exertion while performing treadmill work. Ekblom and Goldborg (1971), Henriksson et al. (1972), and Pandolf and Noble (1973) have indicated that the local factors appear to be the dominant influencing factors of the perception of exertion while performing on the bicycle ergometer.

Kinsman and Weiser (1975) proposed a pyramidal schema for the underlying factors influencing the perception of exertion. The basis for the perception of exertion appears to be the integration of a multitude of various physiological responses.

Several investigators have studied the effects of heart rate on the RPE (Borg and Linderholm, 1967; Ekblom and Goldborg, 1971; Noble et al., 1973b; Pandolf et al., 1972; Patton et al., 1975). Pandolf et al. (1972) manipulated heart rate through the use of environmental heat. Treatments were designed to produce equal heart rates for unequal work loads. Perceived exertion does not seem to be a function of a single physiological parameter such as heart rate, but possibly involves a more integrated set of physiological parameters. Similar conclusions were reached by Noble et al. (1973b). Ekblom and Goldborg (1971) reached a slightly different conclusion after studying the relationship between the RPE and different physiological variables under the following three conditions: (1) alteration of HR by use of autonomic nervous system blocking agents, (2) different types of physical work, and (3) before and after an eight week training period (i.e., cross country running 5-7 days per week). Heart Rate was found to mirror the physical strain subjectively experienced in most work loads but was altered during the treatments utilizing the blocking agents; therefore, HR did not appear to be the primary factor for the establishment of the RPE.

Borg and Linderholm (1967) noted that after testing various age groups, exercise at a given pulse rate was perceived to be heavier by old subjects than by young ones. Therefore, pulse rate did not appear to be the only factor influencing the RPE.

Patton et al. (1975) compared RPE and HR between active and less active army service men. Both groups underwent a six min. run at 6 mph, 0% grade on the treadmill. Heart rate increased linearly with time, reaching a steady state in both groups by five min. Perception of an absolute workload was not reflected by differences in fitness due to training as demonstrated by VO_2 max and submax HR. Training, at least running 2-4 miles per day, does not alter the underlying physiological responses responsible for altering the RPE scores.

Numerous investigations have been performed in an effort to identify the differences between running and cycling, (Cafarelli & Noble, 1975); walking and running, (Horstman, Morgan, Cymerman, & Stokes, 1975; Michael, Durnin, Wormsley, Whitelaw, & Norgan, 1972); cycling, (Pandolf & Noble, 1973; Stamford & Noble, 1974; Robertson et al., 1976); and treadmill work (Michael & Hackett, 1972).

After looking at the changes in VE, HR, RPE, VO_2, and venous lactate concentration, Michael et al. (1972) noted that walking and running resulted in comparable physiological and perceptual responses when the same relative intensity was used. The exception to this was that ventilation parameters were lower during walking than running. When subjects were given an opportunity to regulate their own work bout for 15 min., the physiological data appeared to be the key for the work loads selected. Michael and Hackett (1972) reported that the selection of work intensities on the treadmill vs. bicycle exercise were not similar since VO_2, ventilation and HR were consistently lower on the bicycle ergometer. Oxygen debt was also not related since treadmill O_2 debt was double that of the bicycle exercise even though the subjects felt they were exercising at the same level.

Pandolf and Noble (1973) investigated the Ratings of Perceived Exertion at various pedalling speeds with equivalent power outputs and then evaluated the relationship between pedalling speed (i.e. 40, 60 and 80 rpm cadence) and physiological factors responsible for an individual's subjective estimate of exertion while cycling. Robertson's study (1976) was similar in that power outputs were held constant while pedalling rates were assigned at random (i.e. 40, 60 or 80 rpm cadence). Pandolf and Noble (1974) found that the RPE at equivalent power outputs were negatively related to pedalling speed although the difference between 60 and 80 rpms was not significant. Differences in RPE were more pronounced at the higher power outputs. These cumulative results indicate that when testing subjects on a bicycle erogometer, power output adjustments should be between 60 and 80 rpms rather than 50 and 60 rpms.

Stamford and Noble (1974) reported that (1) RPE scores differ significantly among pedalling rates even though metabolic costs are equivalent, (2) pedalling at 60 rpms was perceived as the least stressful rate, and (3) 60 rpms was not perceived to be significantly more stressful than intermittent work performed at 40 or 80 rpms in spite of the elevated metabolic cost for continuous work. Thus they suggest that factors other than metabolic cost may strongly influence RPE. Again local factors are indicated as possible contributors to RPE scores.

Purpose of the Study

The purpose of this study is (1) to investigate and identify the relative influences of certain physiological responses to the Ratings of Perceived Exertion at specific points in an exercise bout and (2) to explore the influence of bicycle training on Ratings of Perceived Exertion.

Research Hypotheses

1. The RPE will be influenced differently by VO_2, VCO_2, HR,

oxygen pulse (OXP), respiratory quotient (RQ), Na, K+, and LA at different stages in the exercise bout. Oxygen consumption and VCO_2 will be more influential on the RPE during the latter stage of exercise. Heart rate will be the single most influential variable on RPE. Respiratory quotient will be more influential on the RPE in the early stage of exercise while OXP will be more influential during the latter stage. Sodium, K+ and LA will be more influential during the latter stage. The RPE will be lower in the post test due to alterations of these physiological components.

2. On the post test heart rate (HR) at the same relative work load will decrease as a result of training, lowering the RPE.

3. Oxygen consumption (VO_2) will increase at the same relative load, decreasing the RPE. Carbon dioxide production will increase as a result of training due to the increased consumption of O_2 during heavy work, thus lowering the RPE.

4. Lactic acid (LA) will decrease as a result of training, lowering the RPE.

Operational Definitions

Rating of Perceived Exertion

The RPE is the subjective perception of exertion expressed as a numeric value from 6 to 21.

Oxygen Consumption

The amount of oxygen consumed per minute, expressed in liters (VO_2 l/min.) and in relation to body weight (VO_2 ml/kg/min.) was computed by utilizing the formulas in Appendix E1 for each 30 sec. interval of the 6 minute work bout.

Carbon Dioxide Production

Carbon dioxide production per minute (VCO_2 l/min. and VCO_2 ml/kg/min.) was computed for each 30 sec. interval of the 6 min. work bout utilizing formulas from Appendix E1.

Respiratory Quotient

Respiratory quotient (RQ) is the ratio of CO_2 produced to O_2 consumed, $\frac{VCO_2}{VO_2}$. It was computed for each 30 sec. interval of the 6 min. work bout.

Oxygen Pulse

Oxygen pulse is the amount of O_2 taken out of the blood per pulse beat and is computed by dividing the oxygen consumption by the heart rate taken every 30 seconds.

Sodium

Sodium (Na) was measured from a sample of whole blood which was drawn from the anticubital vein two minutes after the cessation of exercise. Sodium is expressed in milli equivalents per liter (mEq/l).

Potassium

Potassium (K+) concentration in whole blood was determined from a venous sample (anticubital) drawn 2 minutes after the cessation of exercise. Potassium (K+) is expressed in milli equivalents per liter (mEq/l).

Lactic Acid

Lactic Acid (LA) concentration in deproteinized whole blood was determined from a sample taken 2 minutes after termination of exercise. Lactic acid is expressed in milligrams per dilution (mg/dl).

Delimitations of the Study

The following were recognized delimitations of the study:

1. The subjects for this study were limited to 12 male volunteers enrolled in a basic weight training course at Louisiana State University, Baton Rouge, Louisiana, during the spring semester of 1978.

2. The measurement of perceived exertion under testing conditions was limited to bicycle ergometer exercise of six min. duration utilizing Borg's scale for the interpretation of perceived exertion.

3. The work load was limited to a maximal heart rate of 180 beats per minute.

4. The training program was confined to exercise bouts on the bicycle ergometer.

5. Blood samples for the analysis of lactic acid, Na, and K+ and their influences on RPE were drawn two minutes after termination of the bicycle ergometer testing period.

Limitations of the Study

This study was conducted with the following limitations:

1. Subjects in the study were instructed not to engage in strenuous physical activity, eat, smoke, or consume alcoholic beverages for at least two hours prior to testing. Vigorous exercise was also to be avoided on the testing day. However, it was not possible to insure that all 12 subjects abided by the requested guidelines.

2. The length of the exercise bout and the continuous nature of the exercise could possibly invoke different psycho-physical responses than found in other forms and durations of exercise.

3. The inability to sample blood for analysis throughout the exercise bouts may have masked any significant influences of those physiological responses at specific points in the exercise.

Significance of the Study

Perception of effort, as related to exercise, is of concern to researchers, practitioners, and subjects who deal with performance and performance variables. Perception of effort appears to be a limiting factor in performance, whether the program is prescribed or volunteer. Because the perception of exertion increases as an individual performs, Kinsman and Weiser (1975), Michael et al. (1972), Pandolf et al. (1972), and Patton et al. (1975) have suggested that the perception of exertion is influenced by various physiological factors. Few attempts have been made to date, however, to identify the physiological variables responsible for influencing the Rating of Perceived Exertion (RPE) to the greatest extent at specific points in an exercise bout.

It is well known that training enhances physical performance. A significant portion of the increased performance may be attributed to alterations in the physiological profile of the subject. However, it is not clear how training affects RPE. Moreover, it is unclear as to whether or not training promotes a substantial reduction in the RPE as it directly correlates with a reduction in physiological changes. Therefore, the effects of training on RPE should be further investigated.

Because RPE relies on incoming perceptual data supplied through physiological adjustments, the RPE might be functioning as a monitor as well as a stress indicator. Perhaps, if specific influencing factors are identified and the subject is trained to recognize the monitoring signals, then possibly individual adjustments can be made to enhance performance.

There is a need for controlled studies in which the physiological factors can be measured and their relative influence on RPE estimated. Training effects on physiological factors as related to RPE also need further investigation.

CHAPTER II

METHODS

Overview of the Study

The study was conducted at Louisiana State University, Baton Rouge, Louisiana, during the spring semester of 1978. The subjects ranged in age from 18 to 26 years.

Prior to the training program, subjects were tested for Ratings of Perceived Exertion (RPE) on the bicycle ergometer. Heart rate, RPE, and respiratory data were collected throughout the testing periods at 30 sec. intervals. Blood samples were collected after termination of the exercise bout for analysis of blood lactate, sodium, and potassium. Upon termination of the training period subjects were tested on the same parameters as in the initial test.

A stepwise regression analysis was utilized in order to determine the statistical significance of the independent variables (heart rate, respiratory data, sodium, potassium and blood lactate) on the dependent variable (RPE). Analysis of the data was performed for both the pre and post tests. A split plot analysis of variance was employed to test the effects of the training period on the variables and on the Ratings of Perceived Exertion.

Selection of Subjects

Subjects for this study were 12 males enrolled in a basic weight training course in the Department of Health, Physical, and

Recreation Education at Louisiana State University, Baton Rouge, Louisiana, during the spring semester of 1978. Mean physical characteristics of the subjects were: age, 20.42 ($\pm$2.58) years; height, 100.02 ($\pm$9.01) cm; and weight, 74.59 ($\pm$7.63) kg. The volunteer subjects underwent a PWC_{180} test in order to establish the maximal work load (HR_{180}) which could be maintained for 6 minutes on the bicycle ergometer.

An abstract of the purpose and procedures to be used in the study and a Standard Departmental medical consent form were given to all subjects.

Instrumentation

Borg Scale

The 15 point graded category scale as developed by Gunnar A. V. Borg was utilized for quantifying the ratings of perceived exertion (Figure 1).

PWC_{180}

The PWC_{180} test was utilized to estimate the physical working capacity of the subject. The test consisted of two consecutive 6 min. bicycle ergometer rides in which the work loads were selected to produce heart rates of approximately 140 and 170 beats per min. Working capacity was then calculated by plotting the heart rate against the work load at the end of each trial. From the intersection of the diagonal line with the HR_{180} a vertical line was drawn to the predicted work load (PWC_{180}).

Monark Bicycle Ergometer, Model 850

The Monark Bicycle Ergometer was employed as the testing and

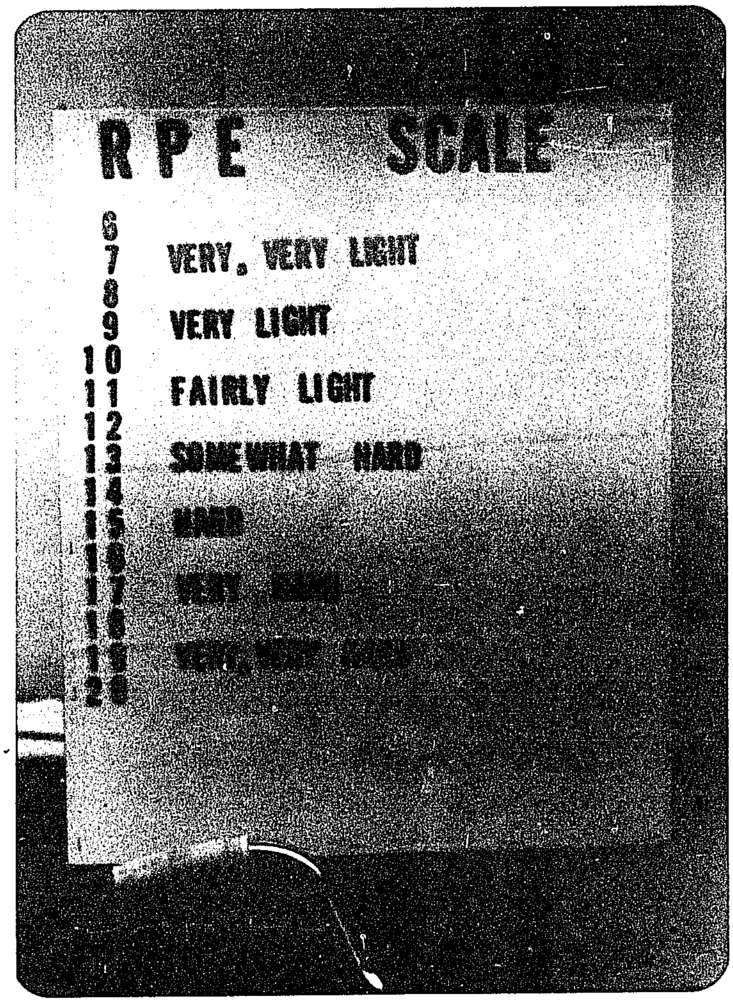

Figure 1. Gunnar A. V. Borg's RPE Scale

training instrument. The workload in kilogram meters per minute (kgm/min.) was the product of the net force multiplied by the distance traveled per unit of time (Figure 2).

Stop Watch

One stop watch was utilized for the time measurements. The stop watch was accurate to .1 of a sec.

Cardio-tachometer

A model QI-609 Exercise Cardio-tachometer was utilized to measure heart rate responses of the subjects. Measurement of heart rate by the cardio-tachometer involved the utilization of shielded leads connected to an isolation pre-amplifier which was attached to a waist belt and connected to the main display panel by a standard electrical jack. The second component consisted of the control panel and display unit, which provided instantaneous or 20 sec. averaging of heart rate data (Figure 3).

Pre-amplifier Power Supply

The power supply for the cardio-tachometer pre-amplifier was two 9.0 volt mercury batteries (Mallory Type TRI46X or equivalent).

Spirometer

A KL Engineering Model S-300 spirometer was utilized to measure inspired ventilation gas during exercise (Figure 4).

Gas Analyzers

Beckman Model LB-2 and OM-11 Medical Gas Analyzers were utilized to analyze the expired carbon dioxide and oxygen, respectively (Figure 5).

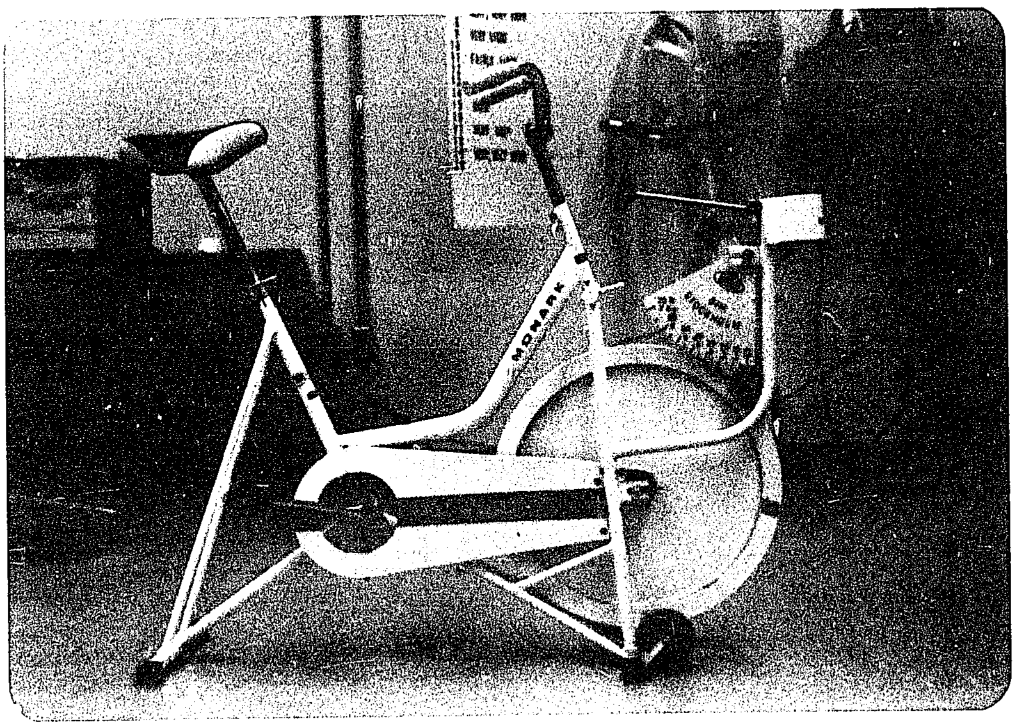

Figure 2. Monark Bicycle Ergometer Model 850

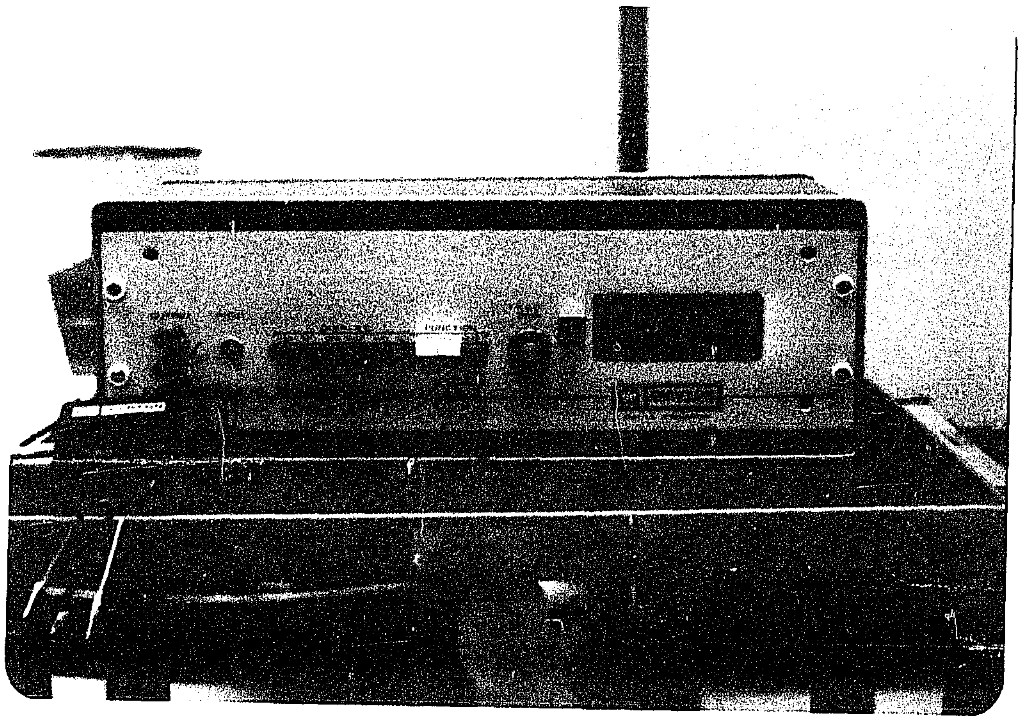

Figure 3. Quinton Exercise Cardio-tachometer model 609 and Pre-amplifier Supply

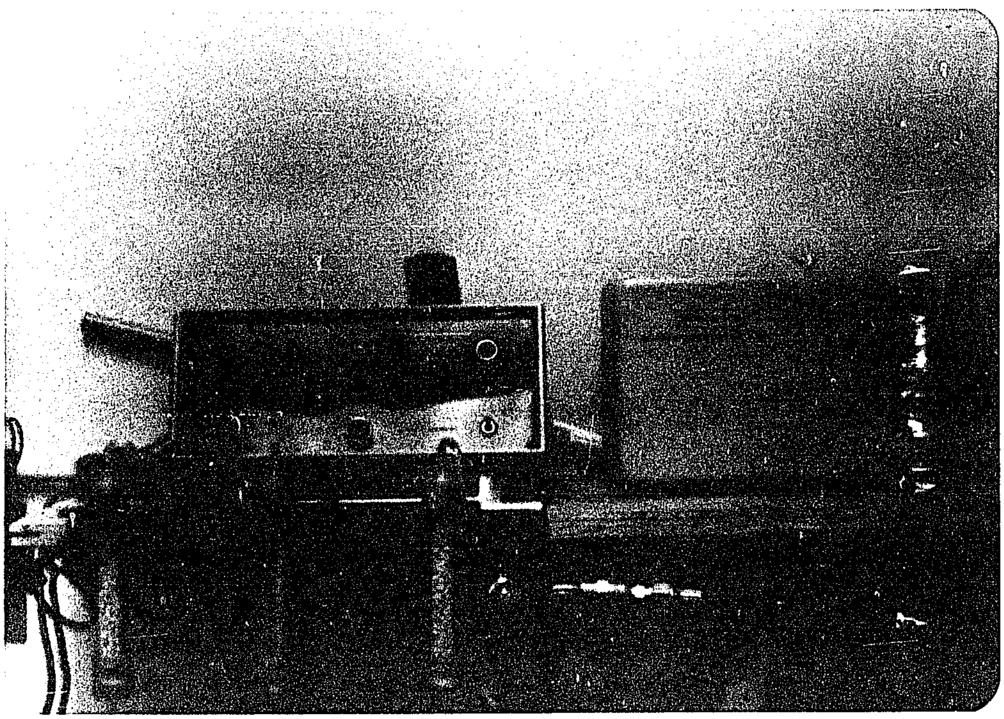

Figure 4. KL Engineering model S-300 Spirometer

Figure 5. Beckman LB-2 Medical Gas Analyzer (top)

and OM-11 Oxygen Analyzer (bottom)

Thermometer

An indoor thermometer was located above the testing area. Room temperature was maintained between 72 and 78 degrees Fahrenheit (22 and 25 degrees Centigrade).

Metronome

An electronic metronome was utilized to set the pedalling cadence for the bicycle ergometer.

Testing Procedure

General Procedure

Each subject's heart rate and ventilation gases were monitored throughout the perceived exertion test. The bicycle ergometer was utilized to regulate the designated work loads for each subject.

Prior to the application of the electrodes, the skin surface area at the site of each electrode attachment was thoroughly cleansed and shaved to ensure maximum bonding and electrical conduction between the subject's body and the electrode. The preamplifier belt was positioned around the subject's waist and the shielded leads were connected to the proper electrode with alligator clips. Upon completion of the above procedure the subject was positioned on the bicycle ergometer and the seat height adjusted so that maximum knee extension (109 degree extension) was achieved during the testing period.

Each subject was fitted with the three way valve, mouthpiece, and head band (Figure 6). The gas analyzers, spirometer and mixing chamber were positioned to the side of the subject and were easily accessable to the experimenter.

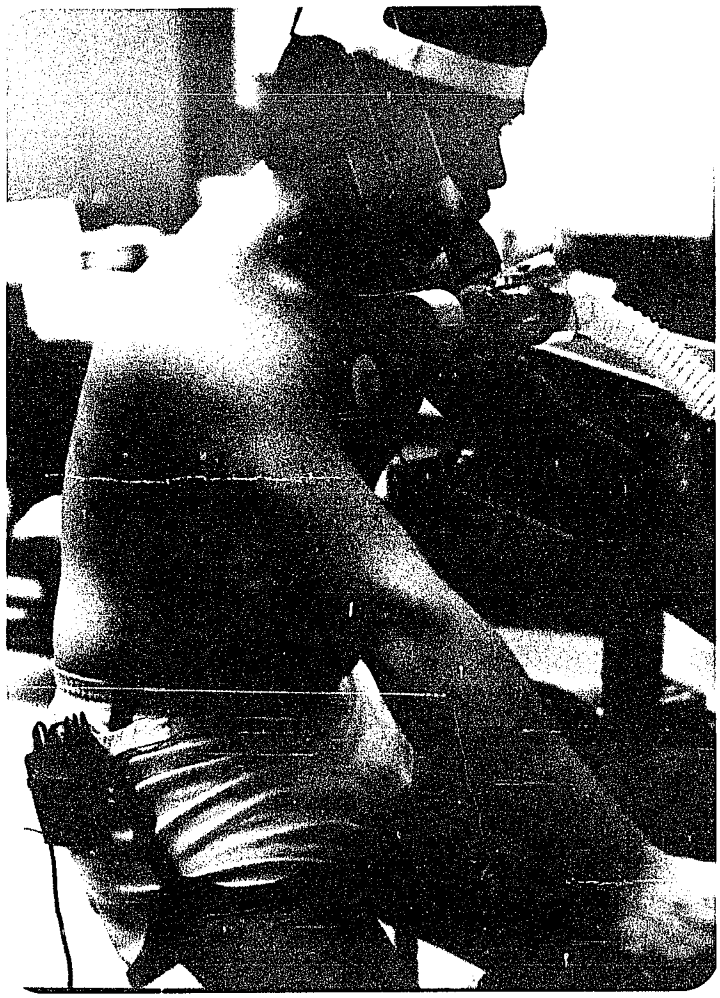

Figure 6. Subject fitted with head gear, three way valve, Spirometer head, electrodes and cardio-tachometer pre-amplifier supply.

Perceived Exertion Test Procedures

The rating scale developed by Borg (1973) was utilized to assess the Ratings of Perceived Exertion (RPE) for each subject while performing on the Monark Bicycle Ergometer. Subjects were given a detailed set of instructions which explained the evaluation of feelings of exertion and the transformation of the subjective feelings into numerical values. The instructions were the same as those which were utilized by Noble et al. (1973b). Subjects were instructed to select the number which most accurately corresponded to his feeling of exertion at that period in the exercise bout. It was emphasized that there were no right or wrong numbers.

On signal, the subject began pedalling at 60 rpm. The pedalling rate was established with the help of an electronic metronome set at a cadence of 120 rpm. As quickly as the subject established the proper pedalling rate, the individualized work load established by the PWC_{180} test was adjusted on the Monark Bicycle Ergometer. The work load was maintained throughout the 6 min. work-bout (Figure 7). At the end of each 30 sec. period of work the subject was instructed to point to the RPE number which best corresponded to his evaluation of the exertion experienced at that instant (Figure 8). All RPE numbers were recorded on the prepared data sheet along with the corresponding heart rate (HR), oxygen percentage (VO_2), carbon dioxide percentage (VCO_2), ventilation (V) and temperature (T). After the completion of the 6 min. testing period, the subject was instructed to assume the resting position on the bicycle

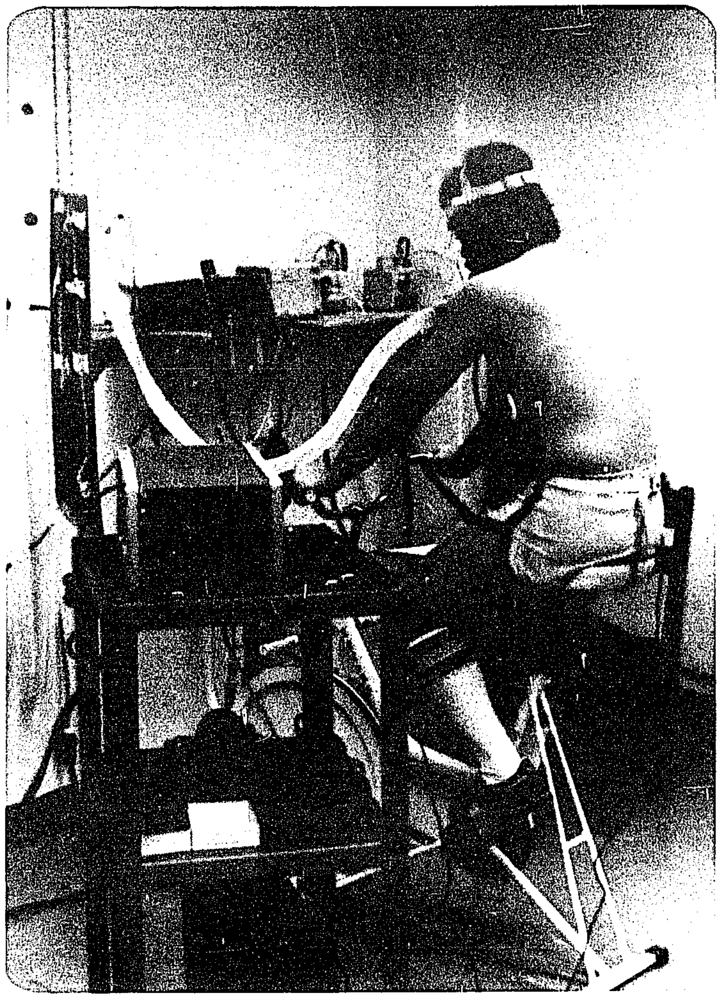

Figure 7. Test subject undergoing RPE test protocol

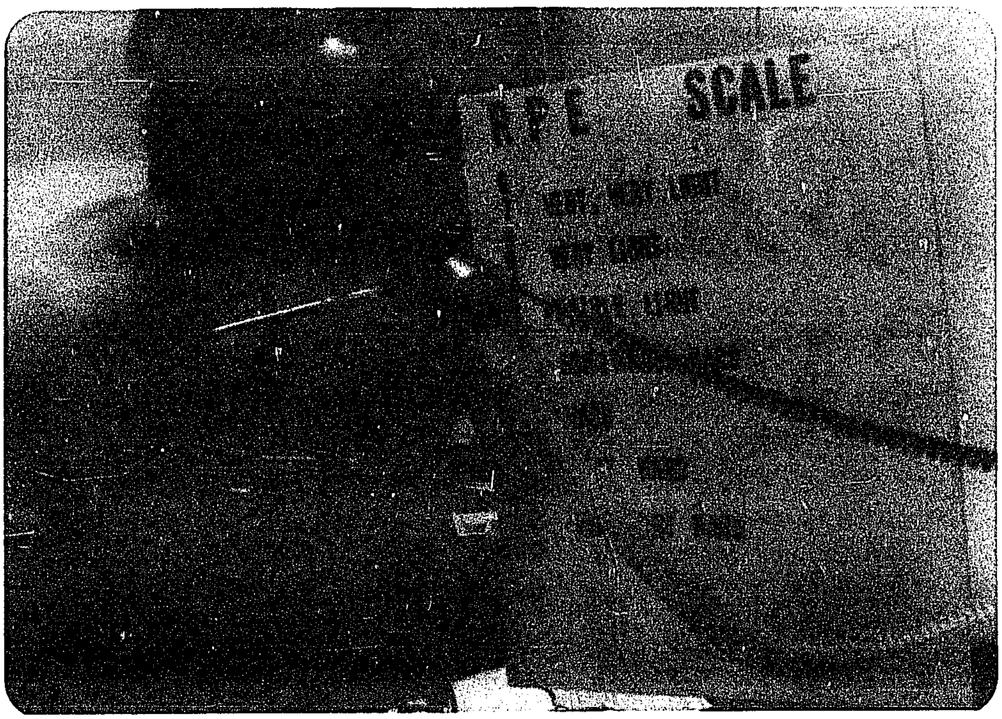

Figure 8. Subject pointing to the numerical rating of perceived exertion

ergometer while all testing instruments were quickly disconnected. Each subject then immediately walked to a desk positioned approximately 15 feet away. After a 2 min. period had elapsed, a blood sample was drawn by venipucture from the anticubital vein (Figure 9) to be used in the analysis of venous blood lactate (LA), sodium (Na) and potassium (K^+). The samples were drawn by an exercise physiologist from the Department of Health, Physical, and Recreation Education at Louisiana State University, Baton Rouge, Louisiana.

Gas Collection Procedures

An open circuit gas collection system was utilized for the collection and evaluation of the respiratory metabolic data. Gas samples were collected during the exercise bout and delivered to the Beckman O_2 and CO_2 analyzers via the spirometer. While the subjects were exercising the metabolic gases were continuously analyzed and the data were recorded during each 30 sec. interval of the 6 min. exercise bout. All O_2 and CO_2 data were recorded in percent concentration and later used to calculate VO_2 and VCO_2 in l/min. and in ml/kg/min. The Respiratory Quotient (RQ) and Oxygen Pulse (OXP) were then calculated using the VO_2, VCO_2, and HR data.

Blood Lactate Collection Procedures

The blood samples were drawn into a 12 cc syringe utilizing a 21 gauge needle without stasis and with as little trauma as possible. After the sample of whole blood was collected in the syringe (approximately 6 cc) the syringe was passed to the experimenter for deproteinization of a 1 cc sample. At this point the needle of the syringe

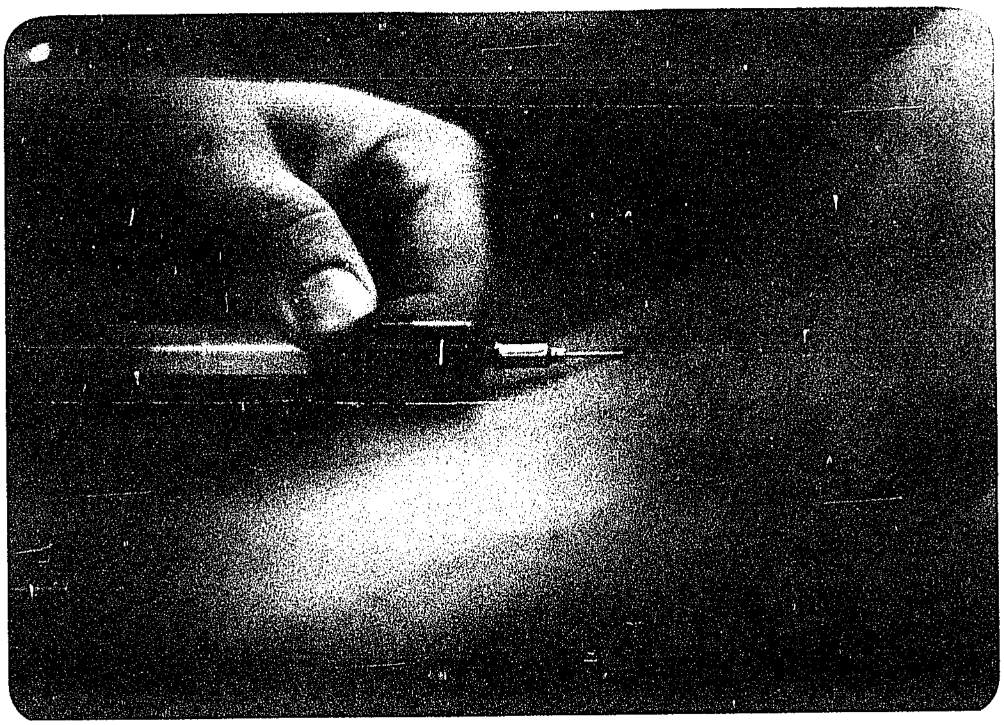

Figure 9. Blood sample being drawn from the anticubital vein.

was removed and quickly discarded. The syringe containing the sample was then relieved of all air bubbles and a small amount of sample was forced out of the syringe so that 1 cc of whole blood could be accurately measured. The whole blood was then transferred to a prepared centrifuge tube containing 2.0 ml of iced 0.6 M perchloric acid. Each tube was covered with Parafilm and thoroughly mixed by inversion.

When the sample turned to a grayish-brown color the mixing was completed and the centrifuge tube was placed directly into a container of crushed ice to cool the sample to 4^{o} Centigrade (Bergmeyer, 1970). A second sample (3-4 cc whole blood) was transferred into a (4 cc) red stopper Becton-Dickenson Vacutainer for the determination of sodium and potassium concentrations in venous blood (Figure 10). The vacutainer was then sealed with the stopper and placed on the table at room temperature. To eliminate the possibility of error with the samples, all vials were coded by number. Samples were analyzed in the School of Veterinary Medicine by the author and several lab technicians from the Animal Science Department. The time lag was never greater than four hours for any blood sample.

Training Procedures

Subjects who completed the initial testing phase (N = 12) were assigned a training schedule to be followed in the weight room in the Gymnasium Auditorium at Louisiana State University. Subjects trained three times per week for 5 weeks on the bicycle ergometer. The subject wore a shirt, shorts and tennis shoes for the training sessions.

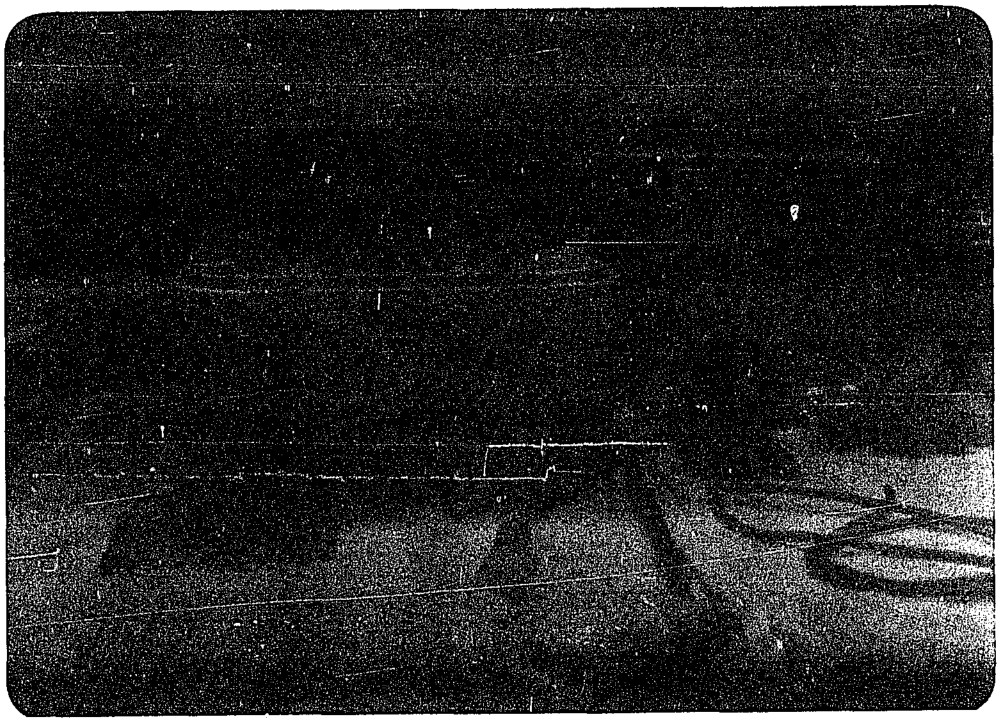

Figure 10. Container of ice containing numbered centrifuge tubes for lactic acid samples, with the 4 cc vacutainers for sodium and potassium samples situated in front.

All subjects began each training period on the bicycle ergometer at a load setting equal to 80% the load setting that was calculated to produce a HR_{180} in 6 min. at a cadence of 60 revolutions per minute.

Each session the subject exercised for a period of 10 minutes or until volitional exhaustion. Workloads were increased by 10% each week until a maximum work load of 120% of the original load was reached. After each training session the subject recorded his name, the amount of time spent on the bicycle ergometer and the work load setting utilized. This was then presented to the supervisor.

After completion of the 5 week training period each subject reported to the physiology laboratory for a post-test evaluation. Subjects were scheduled at the same time on the same day of the week on which they were originally tested so as to eliminate as much biological rhythm and diurnal variations as possible. All testing procedures were identical to the pre-test situation. The subject performed the experiment at the same workload for the same length of time as during the pre-test evaluation.

Statistical Analysis of the Data

Means and standard deviations were computed on all independent and dependent variables. Correlation matrices were generated on the combined data, on pre and post test data and on the first and second 3 minute periods within each pre and post test period. A total of seven correlation matrices were generated from the data collected. A stepwise regression analysis was computed for each three minute time period within each pre and post test evaluation. A (12 X 2) X (12) split plot analysis of variance was used to assess the physiological changes which took place over time and from pre to post test (i.e. HR, RPE, VO_2 l/min., VCO_2 l/min., VO_2 ml/kg/min., VCO_2 ml/kg/min., RQ and OXP). A 12 X 2 factorial design was utilized to explore the changes present for the dependent variables BW, NA, K^+ and LA from pre test to post test.

CHAPTER III

RESULTS

Means and Standard Deviations

Means and standard deviations for the pre and post test data are presented in Table 1. Tables B1 and B2 present the means and standard deviations for the two 3 min. sections of the pre test. Tables B3 and B4 present the means and standard deviations for the two 3 min. sections of the post test.

In Table 1 it can be seen that HR, RPE, RQ, and LA concentration decreased from the pre test to the post test; VO_2 l/min., VO_2 ml/kg/min., VCO_2 l/min., VCO_2 ml/kg/min., and OXP increased from the pre to post test; and Na and K^+ were essentially unchanged.

Correlations

The Pearson r correlations among the dependent variables are presented in Tables A1, A2, A3, A4, A5, A6, and A7. The combined pre and post test coefficient demonstrated a subjstatial relationship (r = .69) for HR and RPE (Table A1). When correlation coefficients were computed between HR and RPE for each test separately, an r = .75 was noted for the pre test while an r = .61 was noted for the post test (Tables A2 and A3). Both HRs and RPEs (Figures 11 and 12) increased linearly during both exercise bouts. Both the RPEs and HRs were lower in the post test. Respiratory quotient correlated (.55) with the RPE, while the VCO_2 ml/kg/min. correlated (.41) with the RPE

TABLE 1

MEANS AND STANDARD DEVIATIONS FOR THE

RPE PRE AND POST TESTS

Variable	N	Pre Test Mean	Pre Test S.D.	Post Test Mean	Post Test S.D.
HR bpm	144*	161.521	14.372	151.840	17.776
RPE	144*	13.847	1.969	11.194	1.940
Ventilation 1	144*	166.430	106.093	178.502	109.769
RQ	144*	1.290	0.194	1.190	0.153
VO_2 1/min.	144*	1.872	0.477	2.337	0.488
VO_2 ml/kg/min.	144*	25.042	5.538	31.192	5.511
VCO_2 1/min.	144*	2.428	0.710	2.802	0.705
VCO_2 ml/kg/min.	144*	32.553	8.796	37.435	8.519
OXP cc	144*	12.000	2.000	16.000	6.000
NA mEq/1	12	146.750	4.079	141.667	1.656
K^+ mEq/1	12	4.367	0.426	4.475	0.515
LA mg/dl	12	73.722	17.448	57.758	19.013
Weight kg	12	74.590	7.363	74.824	6.807

*The N of 144 represents an observation on 12 subjects taken every 30 sec. for 6 min.

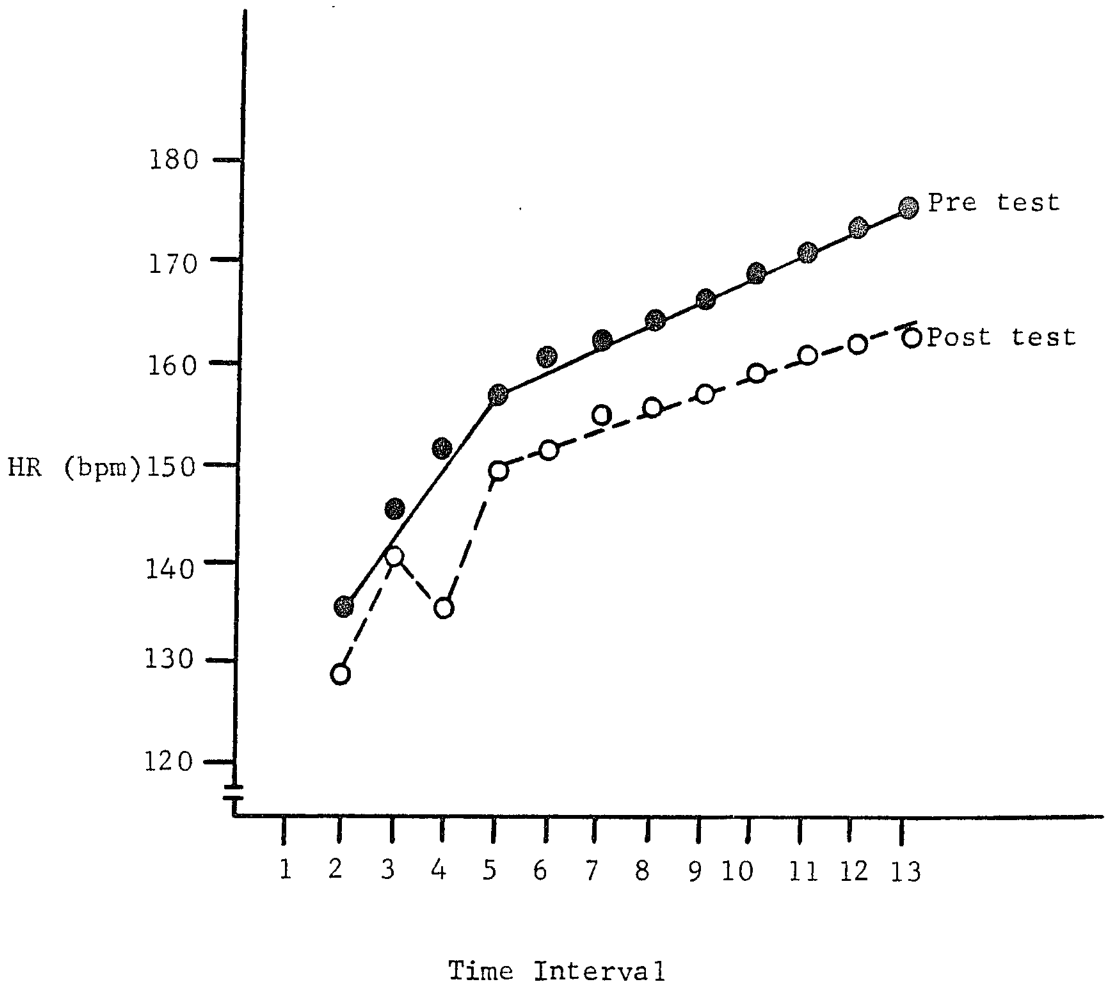

Figure 11. Mean Heart rates for each time interval during the pre test and post test.

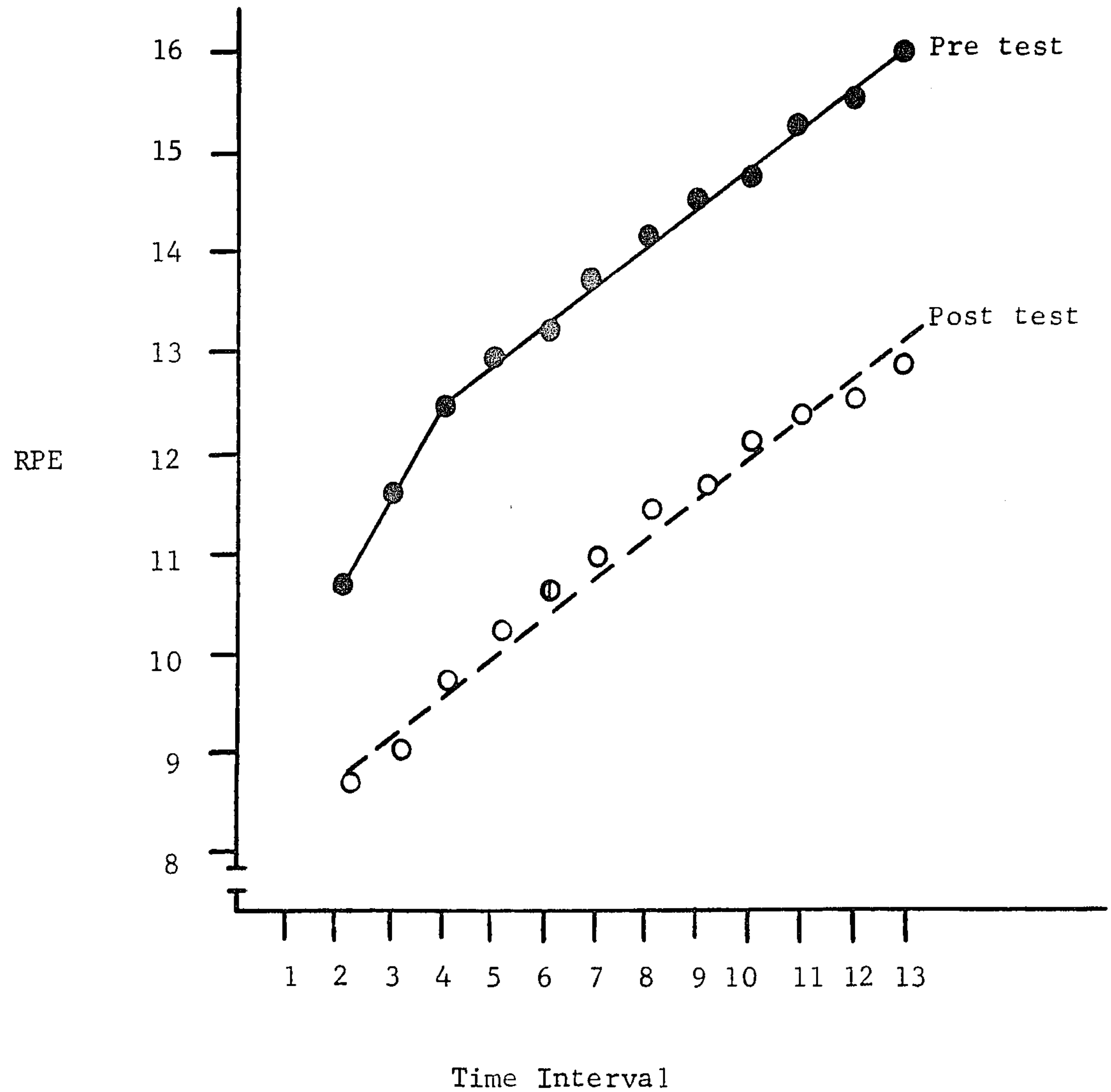

Figure 12. Mean RPE by time plot for each time interval during the pre test and post test.

in the combined pre and post test matrix (Table A1).

When the pre and post test correlations were viewed separately RPE correlated with: RQ (.51), VO_2 ml/kg/min. (.54), and VCO_2 ml/kg/min. (.71) on the pre test (Table A2). The post test correlation matrix displayed slightly reduced relationships between RPE and RQ(.47); RPE and VCO_2 ml/kg/min. (.69); and an increased relationship between RPE and VO_2 ml/kg/min. (.60) (Table A3). The relationships between RPE and Na, K^+, and LA were very low at both the pre and post tests (Na $\underline{r}$ = -.10 and .24; K^+ $\underline{r}$ = -.08 and .13; and LA $\underline{r}$ = .22 and .30; respectively) (Table A2 & A3).

When the pre and post tests were divided into 3 minute early stages and 3 minute latter stages respectively, the Pearson r's between RPE and HR were $\underline{r}$ = .67 and $\underline{r}$ = .48 for the pre test and $\underline{r}$ = .52 and $\underline{r}$ = .49 for the post test (Tables A4, A5, A6, and A7).

The correlation between RQ and RPE for the pre test early stage $\underline{r}$ = .36 was higher when compared to the pre test latter stage r = .22 (Tables A4 and A5). Carbon dioxide production in ml/kg/min. appeared to be substantially related to RPE during the early stage, $\underline{r}$ = .71 (Table A5) but dropped to .43 in the latter stage. Lactic acid displayed a fair relationship to RPE in the latter stage of the pre test, $\underline{r}$ = .42 (Table A5). The post test correlation coefficients of RPE with RQ, VO_2 ml/kg/min. and VCO_2 ml/kg/min. were highest during the early stage.

Analysis of Variance of Ratings of Perceived Exertion and Cardio-pulmonary Measures

Eight (12 X 2) X (12) split plot analysis of variance were used to analyze the dependent variables HR, RPE, RQ, OXP, VO_2 1/min., VCO_2 1/min., VO_2 ml/kg/min. and VCO_2 ml/kg/min.

Heart Rate

Heart rate was shown to significantly increase over time F (11,121) = 64.94, $p < .01$, and there was a significant F ratio for the pre and post test comparison F (1,11) = 12.16, $p < .01$. No significant interactions were noted. In Figure 11, it is evident that the mean HRs steadily increased as the exercise bout progressed. The figure also illustrates the significantly lower HR for the post test.

Ratings of Perceived Exertion

A significant F for time of exercise F (11,121) = 150.08, $p < .01$ and for the pre and post tests comparison F (1,11) = 67.23, $p < .01$ were found for RPE. Figure 12 depicts the linear rise of RPE over time and the significantly lower post test RPE. Figure 13 displays the comparative training effects on HR and RPE.

Respiratory Quotient

The RQ significantly increased as the exercise bout continued F (11,121) = 27.41, $p < .01$. The F for the pre and post test comparison was also significant F (1,11) = 7.63, $p < .05$. A significant test x time interaction was found F (11,121) = 3.13, $p < .01$. Figure 14 illustrates the lower post test RQ and the increases in RQ over time. The interaction can also be seen in that the increases in RQ over time were not the same for the two test periods. Pre test mean RQ

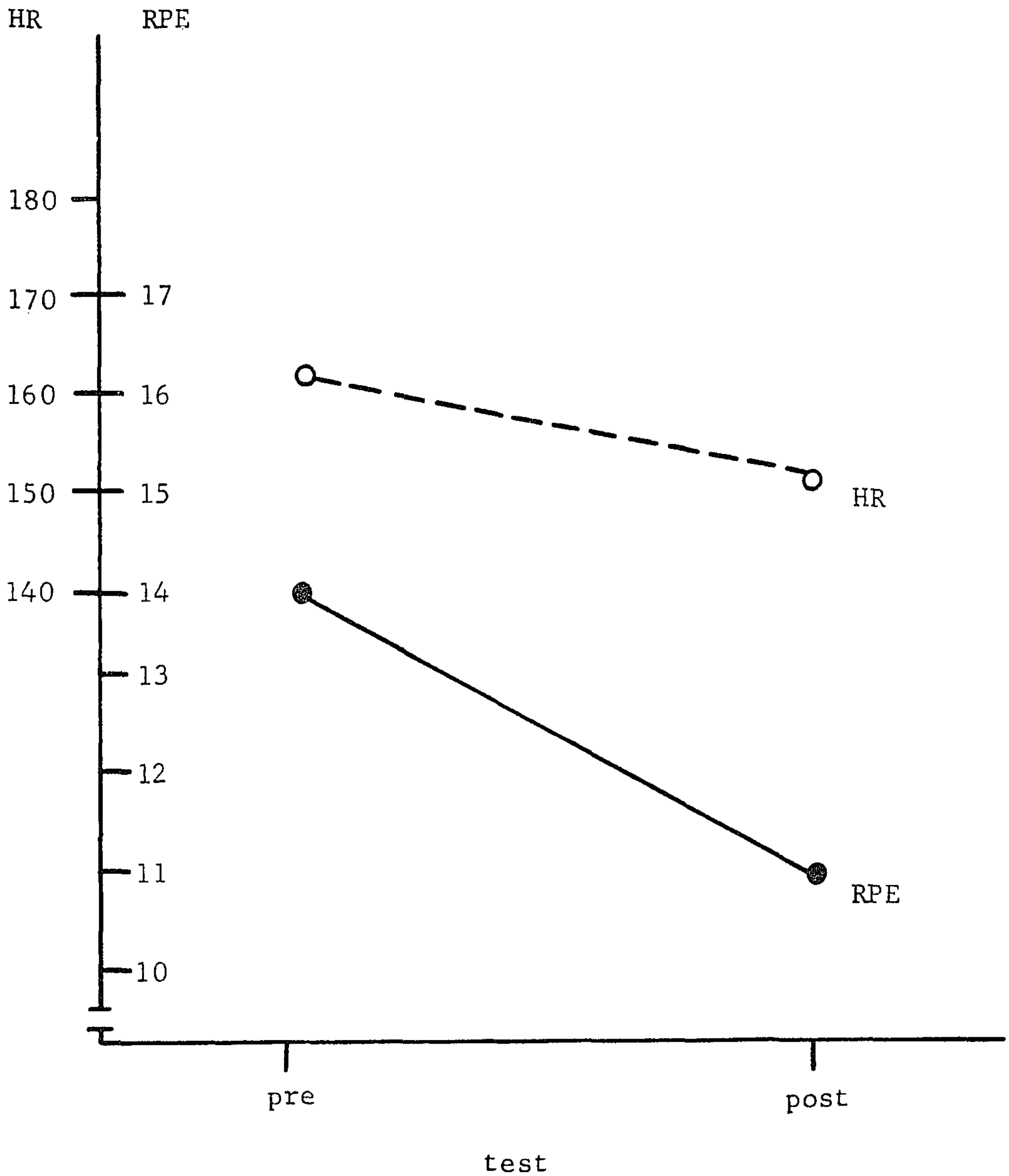

Figure 13. Mean HR and RPE changes between the pre and post tests.

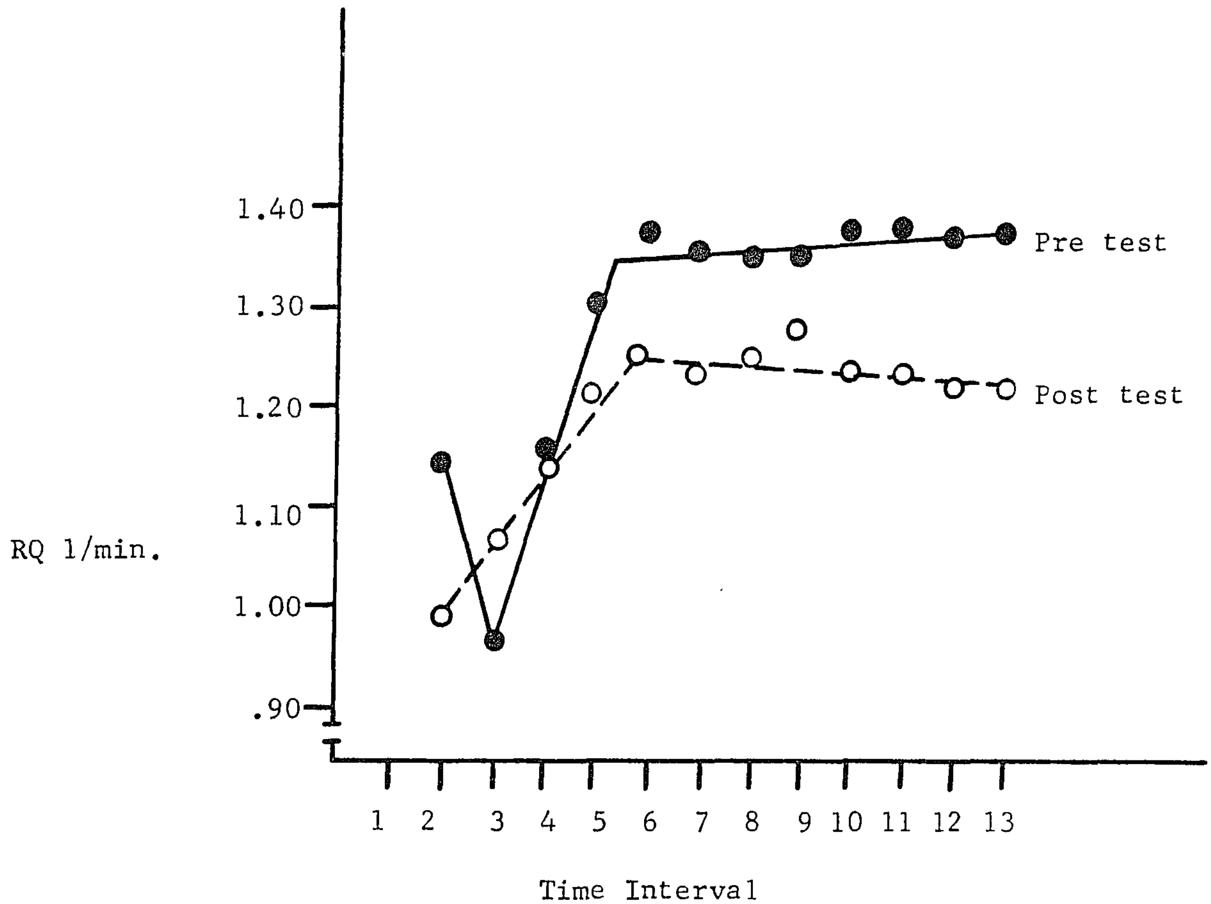

Figure 14. Mean RQ for each time interval during the pre test and post test.

continued to increase while post test RQ decreased.

Oxygen Pulse

Oxygen Pulse measures were shown to be significantly higher in the post test than the pre test F (1,11) = 67.70, $p < .01$. In Figure 15, it can be seen that OXP increased significantly during the initial course of the exercise bout F (11,121) = 2.49, $p \leq .01$ and then leveled off.

Oxygen Consumption in l/min.

Oxygen consumption in liters per minute was significantly greater in test two than in test one F (1,11) = 169.21, $p < .01$. In Figure 16, it can also be seen that VO_2 l/min. significantly increased as the exercise bout continued F (11,121) = 29.78, $p < .01$.

Carbon Dioxide Production in l/min.

Carbon dioxide production in liters per minute was significantly higher in test two than in test one F (1,11) = 14.31, $p < .01$. As seen in Figure 17, VCO_2 l/min. significantly increased as the exercise bout progressed.

Oxygen Consumption in ml/kg/min.

Oxygen consumption in ml/kg/min. increased significantly as the exercise bout continued F (11,121) = 29.45, $p < .01$, Figure 18. The F for the pre and post test comparison was also significant F (1,11) = 162.41, $p < .01$ showing a higher VO_2 in the post test than the pre test.

Carbon Dioxide Production in ml/kg/min.

Carbon dioxide production in ml/kg/min. was significantly larger in test two than in test one F (1,11) = 14.56, $p < .01$. As seen in Figure 19, mean VCO_2 ml/kg/min. significantly increased as the

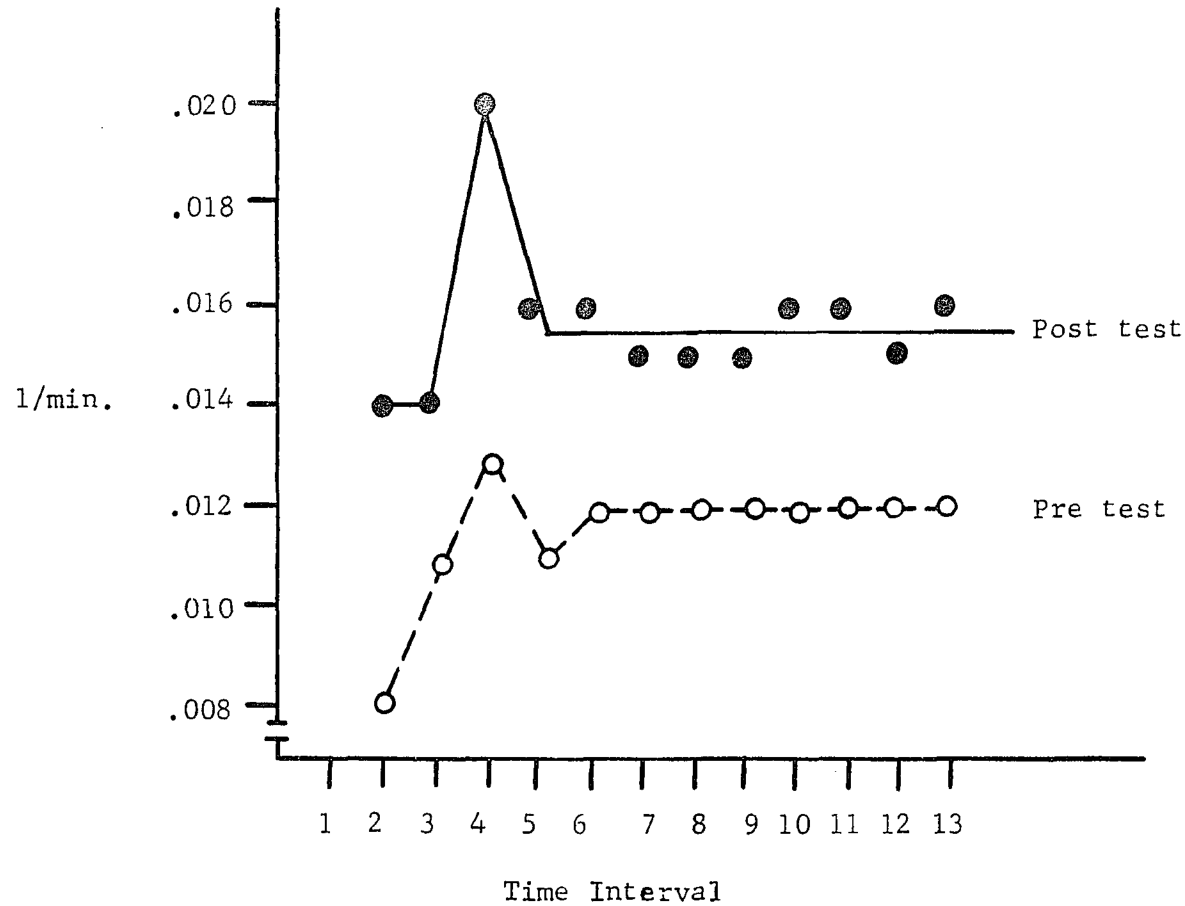

Figure 15. Mean OXP for each time interval during the pre test and post test.

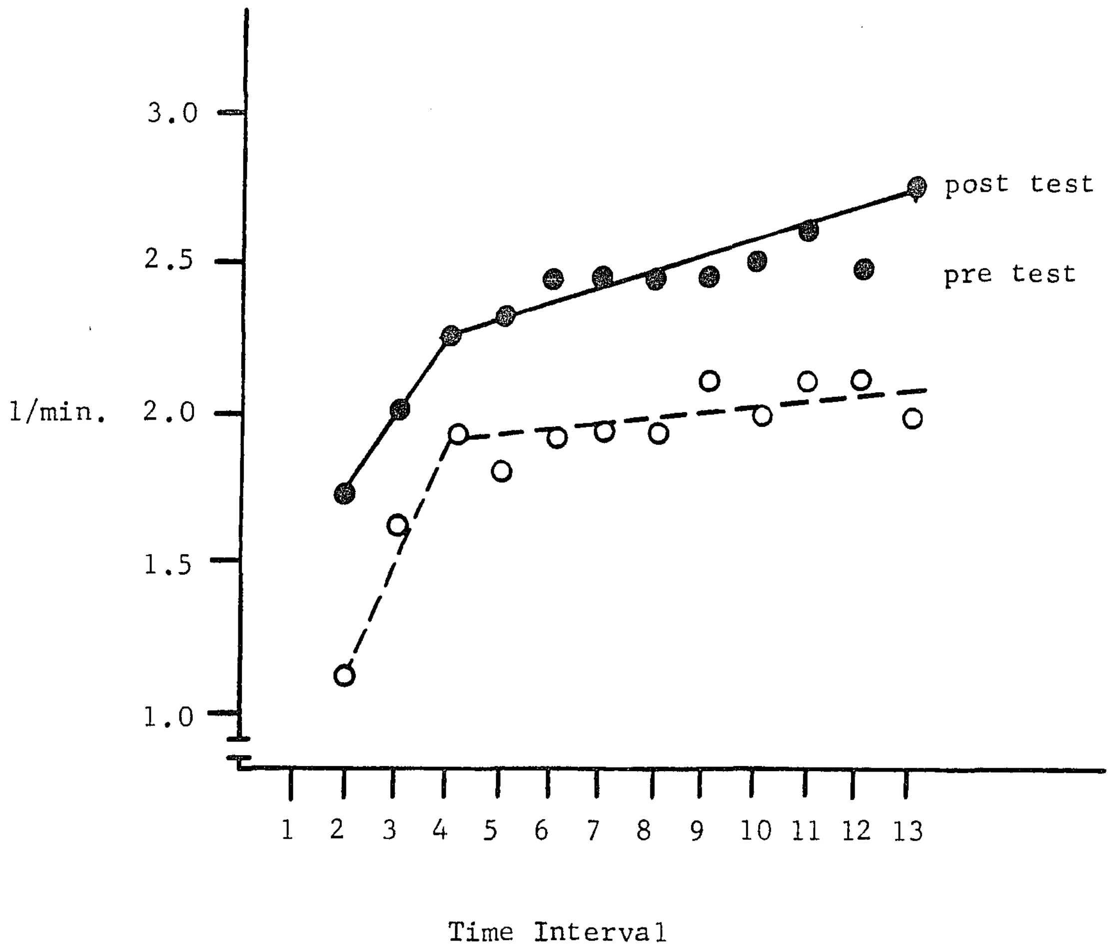

Figure 16. Mean VO_2 l/min. for each time interval during the pre test and post test.

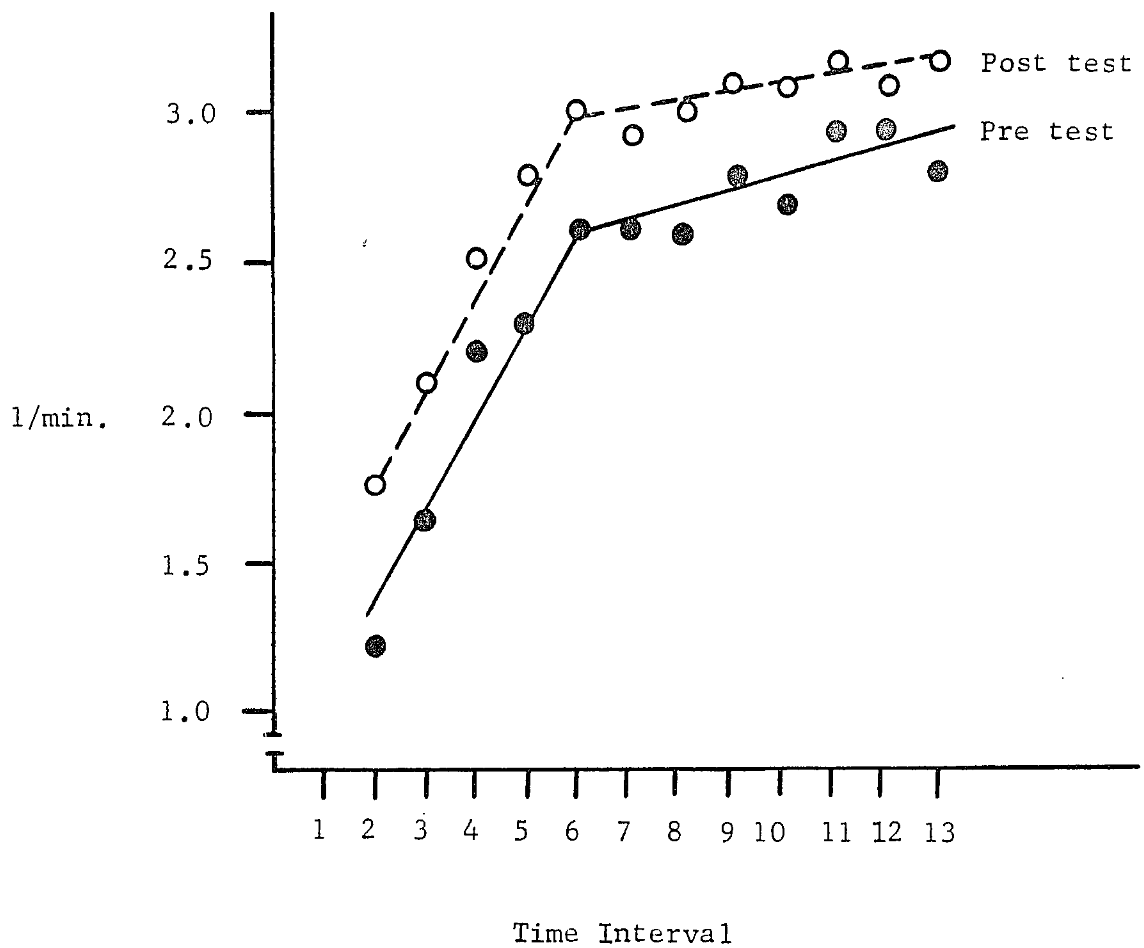

Figure 17. Mean VCO_2 1/min. for each time interval during the pre and post test.

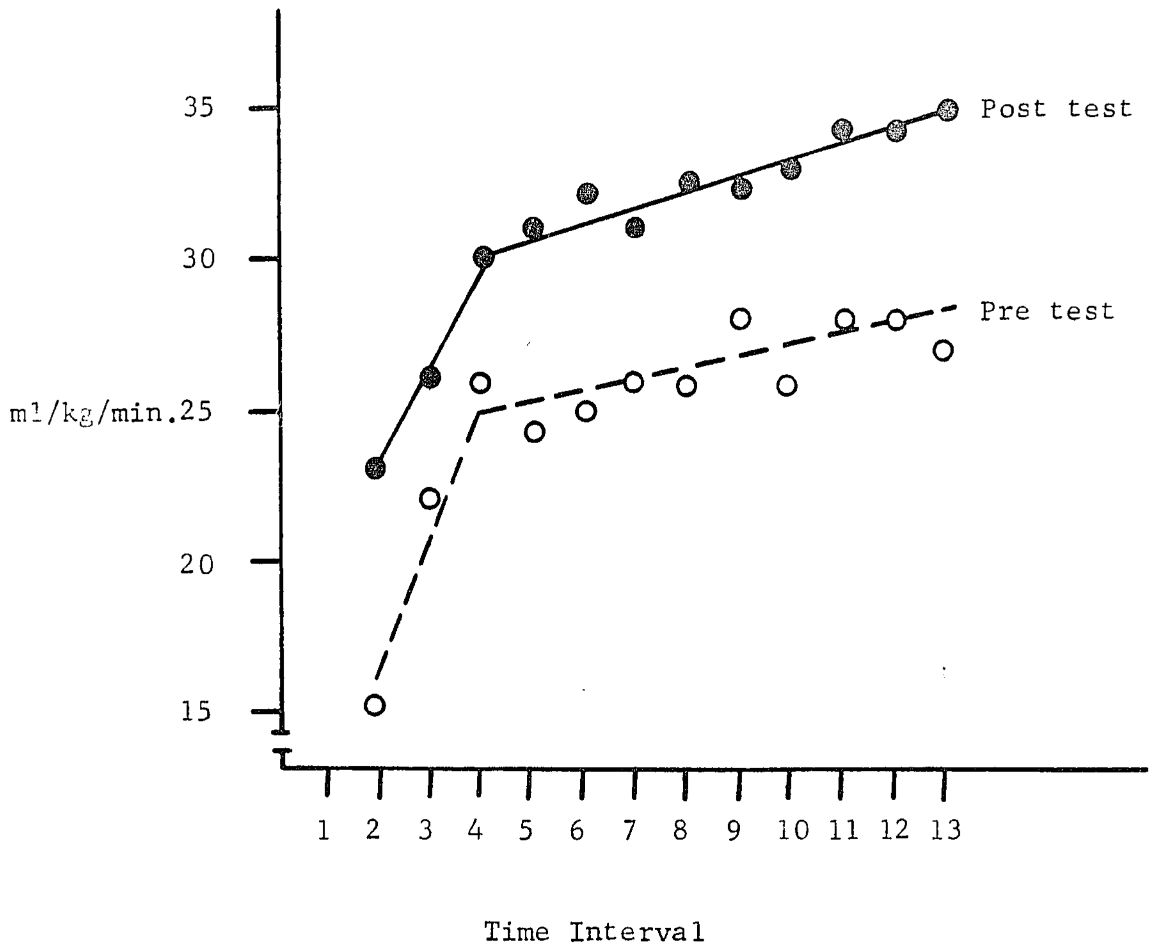

Figure 18. Mean VO_2 ml/kg/min. for each time interval during the pre and post test.

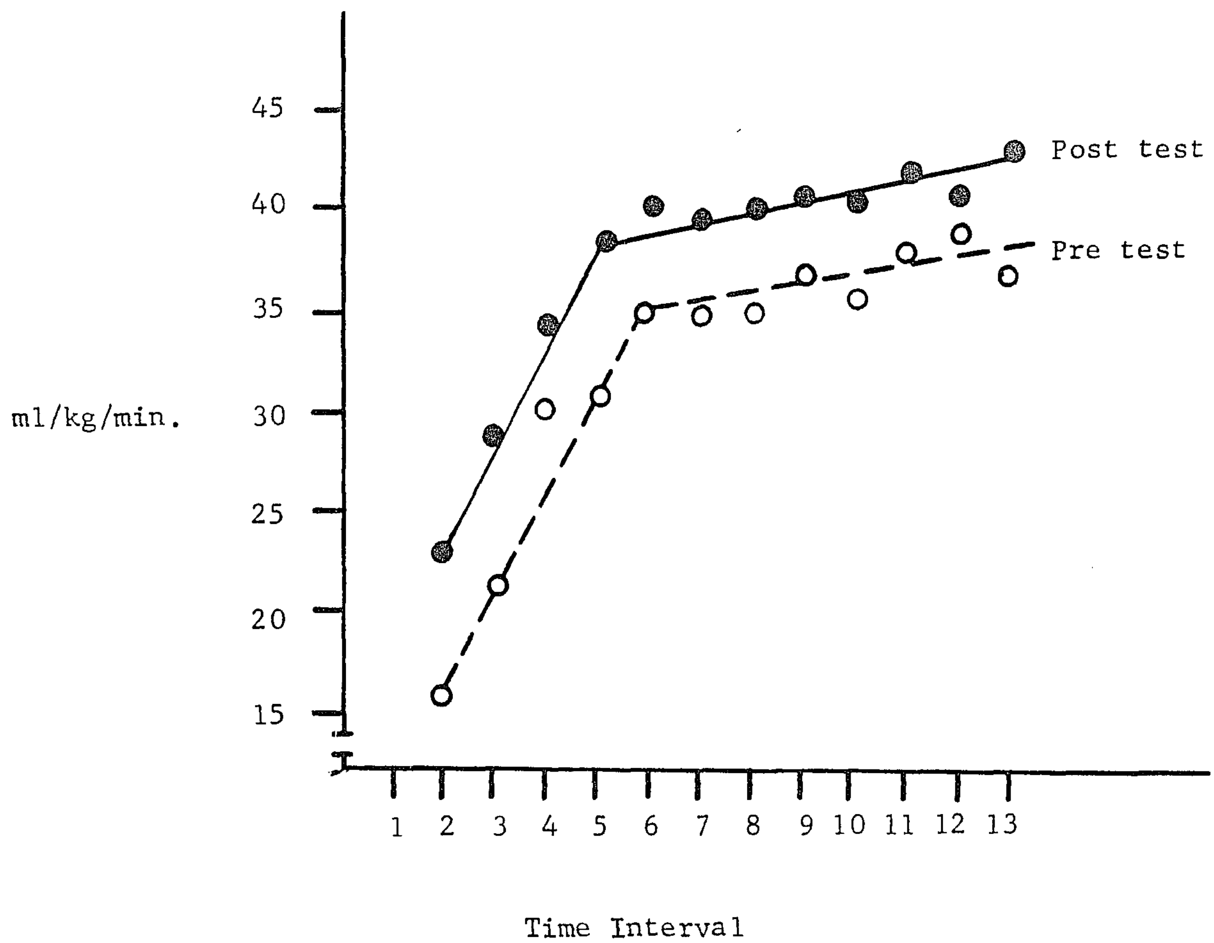

Figure 19. Mean VCO_2 ml/kg/min. for each time interval during the pre and post test.

exercise bout continued.

Analysis of Variance of Sodium, Potassium, and Lactic Acid

In order to ascertain the changes of weight, Na, K^+ and LA from test one to test two a 12 X 2 factorial design was utilized. Table 1 contains the mean values for the variables on the pre and post test.

No significant changes in body weight were evidenced during the experiment (see Table C5). Sodium blood concentration significantly decreased from test one to test two F $(1,11) = 10.43$, $p < .01$. Both the pre and post test values were shown to be within normal ranges. No significant changes in K^+ blood concentration were evidenced (see Table C6). Lactic acid was shown to significantly decrease from test one to test two F $(1,11) = 7.56$, $p < .05$. Table 1 displays the mean LA values for test one and test two.

Stepwise Regression

Stepwise regression was utilized to determine which physiological responses contributed the greatest percentage of variance to RPE. In order to analyze the relative influence of the different physiological variables on RPE at different stages in the exercise, the pre and post test exercise bouts were divided into two, 3 minute periods; the first 3 minute period representing the least stressful stage of exercise and the last 3 minutes representing the more stressful stage of exercise. Two models were developed for each 3 minute time period for the pre and post test. The models used for the first 3 minutes of each test included (1A) HR, RQ, OXP, VO_2 l/min., and VCO_2 l/min. and (2A) HR, RQ, OXP, VO_2 ml/kg/min., and VCO_2 ml/kg/min.

Models used for the last 3 minute intervals of each test were (1B) HR, OXP, RQ, Na, K^+, LA, VO_2 1/min., and VCO_2 1/min., and (2B) HR, OXP, RQ, Na, K^+, LA, VO_2 ml/kg/min., and VCO_2 ml/kg/min.

In the analysis of the first 3 minutes of the pre test, the best regression model for predicting the RPE is shown in Table D1. Four dependent variables were entered into the model with an overall $\underline{F}$ (4,67) = 33.56, $\underline{p} < .01$. All four variables that were entered (HR, OXP, VO_2 1/min., VCO_2 1/min.) contributed significantly to the composite ($\underline{p} < .01$). The $\underline{R}$ for this four-variable model was .83. The $\underline{R}^2$ was .68 which indicates that approximately 32% of the variance (1.00 - $\underline{R}^2$) was unaccounted for by the model. Model 2A for the pre test demonstrated similar results with $\underline{R}$ = .80 and an $\underline{R}^2$ = .64. However, it was noted that OXP was replaced by RQ in the second model and the remaining components were, in order, HR, VO_2 ml/kg/min., and VCO_2 ml/kg/min. An overall $\underline{F}$ (4,67) = 30.10, $\underline{p} < .01$ was obtained. In view of the slightly higher $\underline{R}$, model 1A appears to be the better predictor for RPE during the first 3 minutes of the pre test.

For the last 3 minutes of the pre test, the two models were identical with regard to the size of the $\underline{R}$ ($\underline{R}$ = .76). The regression equation for 1B included HR, VCO_2 1/min., Na and LA. Approximately 42% of the variation is left unaccounted for by both models. However, several differences were observed in the two regression equations. Model 2B's equation includes HR, OXP, RQ, Na, and LA. It should be noted that HR, Na and LA appear in both models.

The regression equations for the first 3 minutes of the post test were quite different from those found for the initial period of the pre test. In model 1A, three dependent variables emerged as the most influential in predicting RPE. The variables HR, RQ, and VCO_2 1/min. produced an R = .73. An R^2 of .53 showed that almost half of the variance associated with RPE was left unaccounted for. In Model 2A only 2 dependent variables were identified: HR and VCO_2 ml/kg/min., R = .71 and R^2 =.50.

The regression equations for the last 3 minutes of the post test are shown in Tables D7 and D8. Model 2B had a slightly higher R than Model 1B, R = .70 and R = .67, respectively. It is noted that HR did not emerge in Model 2B. Over half of the RPE variance was not accounted for by the two models.

Alternative Statistical Interpretation

There are perhaps inherent problems arising in the preceding design of the regression analysis. It was recognized that the data points for the independent variables are probably correlated and that the time factor might also be correlated. Certainly it would be expected that the variables would be affected by time of exercise. Therefore, the data were also analyzed by regressions computed at each 30 sec. interval. The data for the additional analysis are presented in Appendix F.

Neither analysis is entirely satisfactory. In the original analysis, due to the increased df for the error term, the analysis may have over estimated the importance of each factor that was entered into the regression model. Furthermore, the F needed for significance for each factor was reduced considerably due to the inflated df for error.

The second analysis is limited in that the variance was undoubtedly reduced because of the clustering of scores that would be expected for 12 subjects at each 30 sec. interval. Moreover, the reduction in the df for the error term may well have masked any treatment effects because of the magnified error variance. Thus, this analysis would tend to underestimate the relative influence of the physiological factors for predicting the RPE. Therefore, it is suggested that the actual influence of the physiological variables on RPE are possibly less than those predicted from the first analysis but greater than those of the second analysis.

CHAPTER IV

DISCUSSION

The Relationship Between RPE, HR, and Metabolic Variables

Gunnar Borg's scale (Borg, 1973) was based on the concept that RPE and HR possess a linear relationship. As seen in Figure 20, the results of this study support the linear relationship between the Ratings of Perceived Exertion and heart rate. This finding is in agreement with the findings of Bar-or et al. (1972), Borg (1970), and Borg and Linderholm (1967).

Intercorrelations were computed with the physiological variables and RPE. When all the data were combined in a single correlation matrix, the correlation between HR and RPE was $\underline{r}$ = .69, a substantial relationship. The $\underline{r}$ of .69 was somewhat lower than those obtained by Bar-or et al. (1972), Borg (1962), and Skinner et al. (1970). This could possibly be explained by the number of subjects (N =12) in the present study. When correlation matrices were computed for the pre and post test separately, Pearson $\underline{r}$s of .75 and .61 were noted. The lower post test correlation coefficient can be explained due to physiological adjustments which reduced the contribution of HR to RPE and substituted another variable or variables in its place. Therefore, it indicates that through conditioning, the feelings of effort are less influenced by HR while performing at the same workload as before training. Carbon dioxide production (VCO_2 ml/kg/min.)

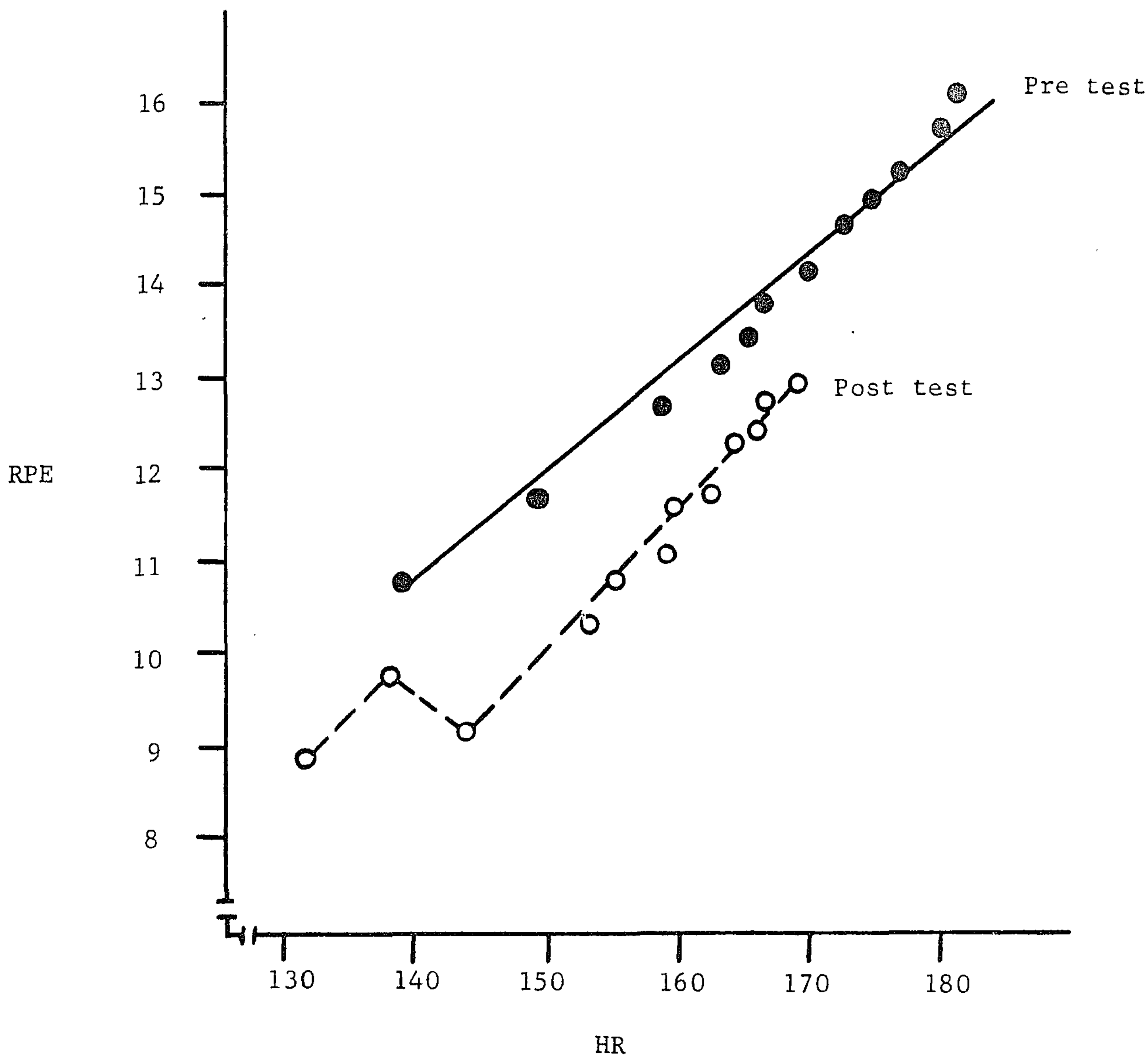

Figure 20. Mean Heart Rates plotted against mean RPE's.

($\underline{r}$ = .71), VO_2 ml/kg/min. ($\underline{r}$ = .54), and RQ ($\underline{r}$ = .51) correlated with RPE during the pre test. At the post test the relationship between RPE and VO_2 increased while the relationships between RPE and RQ and VCO_2 ml/kg/min. decreased. Oxygen consumption (VO_2 ml/kg/min.) was more influential for trained than untrained subjects. Therefore, training increased the efficiency of VO_2 ml/kg/min. for predicting the RPE. The relationships between RPE and Na, K^+, and LA increased from the pre to post test. The above correlations suggest that (1) the correlation between a trained subject's oxygen consumption correlates higher than an untrained subject's and (2) that when trained individuals are evaluated their electrolytes and LA correlate better than untrained subject's. These observations can be explained in part due to the efficiency of the physiological adjustments taking place in an untrained subject vs a trained subject. The only other high correlation coefficients noted were those between the metabolic variables. As would be expected, increases in VO_2 l/min. and VO_2 ml/kg/min. were associated with increases in VCO_2 l/min. and VCO_2 ml/kg/min., $\underline{r}$ = .88 and $\underline{r}$ = .86, respectively.

Influence of Training on the Physiological Factors

Heart rates were shown to significantly decrease from the pre test to post test. This decrease in HR could be attributed to (1) the specificity of the activity, (2) the increased stroke volume (SV) and (3) decreased sympathetic drive. Since the subjects who participated in the study were not accustomed to performing on the bicycle, the HR change from the pre to post test could, at least in part, have been the result of the specificity of the exercise. It is well established that training will bring about increases in SV (Mathews & Fox, 1976). Decreased sympathetic drive is attributed to two factors (1) intracardiac mechanisms and (2) extracardiac mechanisms (Mathews & Fox, 1976). The intracardiac mechanism relies heavily on the increased SV which in turn decreases sympathetic stimulation. Thus HR and sympathetic stimulation are decreased while SV is increased with the same or slightly decreased cardiac output. The extracardiac mechanism is primarily related to alterations in trained skeletal muscle. Sympathetic stimulation of the heart can be altered by nervous impulses from muscles and joints and descending impulses from the motor cortex. Therefore, a reduction in HR occurs as a result of training.

Oxygen pulse was shown to change significantly as a result of training. The OXP is VO_2 l/min. divided by HR which represents the amount of O_2 which can be transported through the circulatory system by each heart beat. The significant decrease in HR and the significant increase in OXP logically points to an increase in stroke volume.

It was found that the mean RQ for the pre test was 1.29 and 1.19 for the post test, which are quite high. However, RQs of up to 1.5 have been reported (Consolazio, Johnson, & Pecora, 1963). An RQ exceeding 1.0 could be explained by hyperventilation and the buffering of lactic acid by sodium bicarbonate. Since Na blood concentrations also changed from pre to post tests, this would give credence to the explanation. Other explanations for high RQs according to Consolazio et al. (1963) are: (1) a washing out of CO_2 due to the increase in LA and increased ventilation; (2) a change in the basal metabolic RQ due to the general increase in utilization of carbohydrate; (3) an indication of the limitations of optimal respiratory functions and, at the same time, of the optimal cardiovascular functions; and (4) a spurious indication of contemporary combustion, spurious because of overbreathing rather than the result of internal combustion. Because all subjects were exercising at a rigorous intensity for a period of 6 minutes, any or all of the explanations presented above could be used to explain the high RQs. Respiratory Quotients decreased from the pre test to post test as did the Na and LA concentrations. With improved physical conditioning the Na buffering was possibly enhanced for the second test, thus decreasing LA. One final explanation for the high RQs noted may have been the specificity of the exercise. Since the leg muscles were primarily involved, possibly during the first test period some of the subjects were actually working at work loads exceeding their VO_2 max. Through training and specific physiological adjustments, primarily in the legs, subjects were able to increase their VO_2 max and lower their HRs during the post test, resulting also in a lowering of the RQs.

Significant increases in VO_2 l/min., VCO_2 l/min., VO_2 ml/kg/min., and VCO_2 ml/kg/min. were found from pre test to post test. The increases appear to be a direct result of training. Again, the specificity of the training could be an important factor (Fox et al., 1975b; Horstman et al., 1975; Michael & Hackett, 1972; Michael et al., 1972; Patton et al., 1975). The most logical explanation for the increased consumptions of O_2 and increased production of CO_2 lies in the experimental design of the study. All subjects were tested using individualized work loads which had been designed to produce HRs equal to 180 bpm at the end of the first 6 minute test. This was essentially accomplished as the mean HR for the last minute was 176.8.

Since a HR of 180 is close to maximal, some of the subjects might have actually reached their physiological limits in the pre test. Therefore, as a result of exercise and conditioning these limits were extended, and when tested under identical conditions subjects were able to elicit higher O_2 uptakes with greater CO_2 production for the post test. One further explanation for the increased metabolic activity may have been changes in skeletal muscle, hypertrophy and increased capillary density primarily in the leg muscles. Trained subjects have higher VO_2 ml/kg/min. when compared to untrained subjects due to increased capillary density. (Hermansen and Wachtlova, 1971). Increases in O_2 consumption during maximal exercise has been well documented (Astrand, 1952; Astrand, Eriksson, Nylander, Engstrom, Korlberg, Saltin & Thoren, 1968; Ekblom, Astrand, Saltin, Steinberg & Wallstrom, 1968; Fox, 1975; Fox, Bartels, Billings, O'Brien, Bason & Mathews, 1975a; Fox et al., 1975b; Saltin, Blomquist, Mitchell, Johnson, Wildenthal & Chapman, 1968). Therefore, since the training period lasted five weeks, 3 days per week, 10 minutes per day at work loads of 80, 90, 100, 110, and 120 percent the initial PWC_{180} estimate and was intensive, the improved condition may largely explain the increases in O_2 consumption and CO_2 production.

Sodium and LA decreased significantly from the pre test to the post test. These decreases were perhaps due to a decrease in the production of LA by the working muscle (Mathews and Fox, 1976) and an increase in buffering systems (Holloszy, 1973). Karlsson (1971) demonstrated that high correlations exist between muscle lactate concentration and the subjective feeling of fatigue. Since plasma concentration of LA is directly related to muscle concentration (Gollnich and Hermansen, 1973), data collected in this study indicate that RPE decreases from pre test to post test (as did LA) suggesting a causal relationship. Hermansen (1971) reported that LA in non-athletes is higher than in athletes at a specific workload. Therefore, training should have resulted in lower LA in the second test using the same work load.

Potassium (K+) evidenced no change from pre test to post test. Potassium (K+) cubital venous concentrations have been shown to be less in trained than in untrained subjects (Tibes, Hemmer, Boning, & Schweigart, 1976). The data collected in this study did not provide any evidence to support Tibes' conclusion. The discrepancy in the finding may be due to the experimental design of this study. In

Tibes' et al. study trained and untrained subjects performed on the cycle ergometer for 50 minutes at 98W (10 mKp/s) power output at 60 rpms. Subjects in the present study worked for 6 minutes utilizing an initial PWC_{180} workload for both tests at 60 rpms. This difference in experimental design could possibly explain the lack of consistency. With increased performance time, one would expect the venous K+ concentrations to rise significantly due to the expulsion of K+ from active muscle.

Influences of Physiological Variables in Predicting RPE

Clearly, during the first 3 minutes of the pre test, the metabolic or respiratory components appeared to be the major influencing factors but when the last 3 minute period was viewed, the anaerobic by-products appeared to be more influential on the RPE. These findings were in agreement with those of Fox et al. (1975b), Horstman et al. (1975), Michael et al. (1972), and Patton et al. (1975) in that the subjective feeling of fatigue was governed by LA, HR and other anaerobic by-products. It should also be noted that the $\underline{R}^2$s account for only 45 to 68 percent of the variance for predicting RPE. Therefore, from 32 to 55 percent of the variance was left unaccounted for. This variance could possibly be accounted for if other physiological substrates were measured and/or if certain psychological characteristics were included in the model.

On the post test, utilizing the identical models as for the Pre test, marked changes were observed in the variables that were stepped in for predicting the RPR. Both of the models used on the post test were equally efficient in predicting the RPE using essentially the same components. The predictive power of the post test equations was less than the pre test. It may be that the altering of the components resulted in less predictive efficiency. Consequently, other physiological or psychological factors must have accounted for the percentage of variance lost in the equations as a result of training.

Summary

This study attempted to investigate the effects of certain physiological components on the Ratings of Perceived Exertion and to explore the influence of training on RPE and on the underlying physiological responses influencing RPE. Heart rates and RPEs increased linearly for both tests with a substantial relationship (r = .69). The correlation for RPE and HR for the post test was lower than the pre test (r = .61 and r = .75). Evidently, the RPEs were reduced and the physiological components were altered due to training. The variables of RPE, HR, RQ, Na, and LA were all reduced while VO_2 l/min., VCO_2 l/min., VO_2 ml/kg/min., and VCO_2 ml/kg/min. were increased. No changes were noted in body weight or K+ concentration.

In reviewing the stepwise regression for four models and two time periods within the pre and post test, the predictor models displayed Rs of .67 to .83. Therefore, from 45 to 68 percent of the variance for predicting the RPE was accounted for by the models. RPE appears to be a multifaceted and multistructural composite of physiological and psychological phenomena with perhaps half of the variance of the RPE associated with the physiological state. Possibly, additional portions of the variance could be due to psychological factors.

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APPENDICES

APPENDIX A

CORRELATION COEFFICIENTS

TABLE A1

Combined Pre and Post Test Correlation Coefficients

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. HR	1.00												
2. RPE	.69	1.00											
3. BW	-.14	.02	1.00										
4. HT	-.04	.09	.51	1.00									
5. NA	.11	.35	.07	-.03	1.00								
6. K^+	-.05	-.04	-.21	-.06	.18	1.00							
7. LA	.27	.42	.23	-.09	.38	-.13	1.00						
8. RQ	.45	.55	-.16	-.17	.31	.14	.27	1.00					
9. VO_2 l/min.	.23	.13	.47	.34	-.21	-.05	-.07	-.05	1.00				
10. VCO_2 l/min.	.41	.39	.36	.23	-.03	.03	.10	.40	.	1.00			
11. VO_2 ml/kg/min.	.31	.14	.10	.16	-.28	.04	-.18	-.01	.91	.83	1.00		
12. VCO_2 ml/kg/min.	.49	.41	.01	.06	-.06	.12	.01	.49	.77	.93	.86	1.00	
13. OXP	.40	-.18	.37	.24	-.20	-.05	-.16	-.19	.62	.47	.54	.37	1.0

TABLE A2

Pre Test Correlation Coefficients

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. HR	1.00												
2. RPE	.75	1.00											
3. BW	-.34	.02	1.00										
4. HT	-.08	.05	.31	1.00									
5. NA	-.19	-.10	.09	-.15	1.00								
6. K^+	-.08	-.08	-.02	.04	.49	1.00							
7. LA	-.04	.22	.14	-.19	.22	-.23	1.00						
8. RQ	.05	.51	-.19	-.14	.12	.06	.15	1.00					
9. VO_2 l/min.	.91	.48	.50	.33	.05	-.05	.07	.02	1.00				
10. VO_2 ml/kg/min.	.52	.54	.11	.15	.02	-.05	.01	.10	.91	1.00			
11. VCO_2 l/min.	.49	.67	.35	.23	.12	-.01	.16	.46	.88	.84	1.00		
12. VCO_2 ml/kg/min.	.65	.71	.00	.06	.09	.01	.12	.57	.75	.86	.93	1.00	
13. OXP	.00	.26	.64	.37	.13	.02	.11	-.12	.95	.78	.77	.57	1.00

TABLE A3

Post Test Correlation Coefficients

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. HR	1.00												
2. RPE	.61	1.00											
3. BW	.03	.06	1.00										
4. HT	.00	.18	.50	1.00									
5. NA	.02	.24	.19	.28	1.00								
6. K^+	.03	.13	-.39	-.15	.11	1.00							
7. LA	.34	.30	.37	.00	.15	.01	1.00						
8. RQ	.37	.47	-.14	-.21	.42	.32	.22	1.00					
9. VO_2 l/min.	.48	.54	.53	.40	.21	-.17	.18	.15	1.00				
10. VO_2 ml/kg/min.	.55	.60	.09	.21	.14	.00	.02	.23	.89	1.00			
11. VCO_2 l/min.	.57	.66	.39	.24	.38	.00	.28	.58	.89	.82	1.00		
12. VCO_2 ml/kg/min.	.61	.69	.01	.06	.33	.16	.16	.68	.74	.86	.92	1.00	
13. OXP	-.47	-.01	.31	.23	.12	-.15	-.04	-.07	.36	.26	.26	.16	1.00

TABLE A4

Correlation Coefficients for Pre Test, Time 30 seconds to 3 minutes

	1	2	3	4	5	6	7	8
1. HR	1.00							
2. RPE	.67	1.00						
3. RQ	.36	.47	1.00					
4. VO_2 1/min.	.41	.43	-.01	1.00				
5. VO_2 ml/kg/min.	.59	.50	.03	.92	1.00			
6. VCO_2 1/min.	.54	.65	.47	.87	.82	1.00		
7. VCO_2 ml/kg/min.	.69	.71	.53	.77	.85	.94	1.00	
8. OXP	.14	.28	-.13	.96	.82	.77	.62	1.00

TABLE A5

Correlation Coefficients for Pretest, Time 3 minutes 30 seconds to 6 minutes

	1	2	3	4	5	6	7	8	9	10	11
1. HR	1.00										
2. RPE	.48	1.00									
3. NA	-.26	-.21	1.00								
4. K+	-.16	-.24	.50	1.00							
5. LA	.08	.42	.23	-.23	1.00						
6. RQ	.15	.22	.22	.10	.35	1.00					
7. VO_2 1/min.	-.22	.27	.10	-.08	.15	-.35	1.00				
8. VO_2 ml/kg/min.	.08	.30	.06	-.10	.09	-.27	.88	1.00			
9. VCO_2 1/min.	-.18	.40	.21	-.02	.38	.11	.89	.80	1.00		
10. VCO_2 ml/kg/min.	.14	.43	.20	-.02	.31	.32	.66	.82	.86	1.00	
11. OXP	-.45	.13	.16	-.04	.15	-.34	.97	.78	.86	.57	1.00

TABLE A6

Correlation Coefficients for Post Test, Time 30 seconds to 3 minutes

	1	2	3	4	5	6	7	8
1. HR	1.00							
2. RPE	.52	1.00						
3. RQ	.30	.57	1.00					
4. VO_2 l/min.	.40	.49	.19	1.00				
5. VO_2 ml/kg/min.	.47	.52	.30	.90	1.00			
6. VCO_2 l/min.	.47	.67	.64	.87	.85	1.00		
7. VCO_2 ml/kg/min.	.50	.67	.75	.72	.85	.94	1.00	
8. OXP	-.65	-.10	-.02	.27	.19	.20	.11	1.00

TABLE A7

Correlation Coefficients for Post Test, Time 3 minutes 30 seconds to 6 minutes

	1	2	3	4	5	6	7	8	9	10	11
1. HR	1.00										
2. RPE	.49	1.00									
3. NA	.04	.21	1.00								
4. K^+	.07	.17	.10	1.00							
5. LA	.59	.47	.15	.01	1.00						
6. RQ	.22	.15	.62	.35	.43	1.00					
7. VO_2 l/min.	.39	.40	.20	-.16	.25	-.20	1.00				
8. VO_2 ml/kg/min.	.43	.45	.12	.05	.08	-.21	.83	1.00			
9. VCO_2 l/min.	.49	.44	.51	.00	.46	.30	.87	.70	1.00		
10. VCO_2 ml/kg/min.	.54	.49	.48	.25	.34	.39	.68	.82	.85	1.00	
11. OXP	.01	.25	.18	-.19	.03	-.31	.93	.74	.74	.51	1.00

APPENDIX B

MEANS AND STANDARD DEVIATIONS

TABLE B1

MEANS AND STANDARD DEVIATIONS FOR

PRE TEST, TIME 30 SECONDS TO 3 MINUTES

Variables	N	Mean	S.D.
RPE	72*	12.583	1.489
HR bpm	72*	152.708	12.598
Ventilation l/min.	72*	76.361	45.900
RQ	72*	1.215	0.218
VO_2 l/min.	72*	1.708	0.464
VO_2 ml/kg/min.	72*	22.882	5.713
VCO_2 l/min.	72*	2.083	0.676
VCO_2 ml/kg/min.	72*	27.953	8.637
OXP cc	72*	11.000	3.000

*N is for 6 observations on 12 subjects.

TABLE B2

MEANS AND STANDARD DEVIATIONS FOR PRE TEST,

TIME 3 MINUTES 30 SECONDS TO 6 MINUTES

Variables	N	Mean	S.D.
RPE	72*	15.111	1.534
HR bpm	72*	170.333	9.989
Ventilation l/min.	72*	256.499	64.107
RQ	72*	1.365	0.131
VO_2 l min.	72*	2.037	0.433
VO_2 ml/kg/min.	72*	27.203	4.436
VCO_2 l/min.	72*	2.773	0.563
VCO_2 ml/kg/min.	72*	37.153	6.188
OXP cc	72*	12.000	3.000
NA mEq/l	12	146.750	4.093
K+ mEq/l	12	4.367	0.428
LA mg/dl	12	73.722	17.510

*N is for 6 observations on 12 subjects.

TABLE B3

MEANS AND STANDARD DEVIATIONS FOR POST

TEST, TIME 30 SECONDS TO 3 MINUTES

Variables	N	Mean	S.D.
RPE	72*	10.083	1.536
HR bpm	72*	143.764	19.390
Ventilation l/min.	72*	85.738	49.385
RQ	72*	1.144	0.177
VO_2 l/min.	72*	2.167	0.476
VO_2 ml/kg/min.	72*	28.904	5.287
VCO_2 l/min.	72*	2.504	0.706
VCO_2 ml/kg/min.	72*	33.474	8.727
OXP cc	72*	16.000	8.000

*N is for 6 observations on 12 subjects.

TABLE B4

MEANS AND STANDARD DEVIATIONS FOR POST TEST,

TIME 3 MINUTES 30 SECONDS TO 6 MINUTES

Variables	N	Mean	S.D.
RPE	72*	12.306	1.650
HR bpm	72*	159.917	11.321
Ventilation 1/min.	72*	271.267	66.155
RQ	72*	1.235	0.107
VO_2 1/min.	72*	2.507	0.441
VO_2 ml/kg/min.	72*	33.480	4.755
VCO_2 1/min.	72*	3.099	0.568
VCO_2 ml/kg/min.	72*	41.397	6.180
OXP cc	72*	16.000	3.000
NA mEq/1	12	141.667	1.662
K^+ mEq/1	12	4.475	0.517
LA mg/dl	12	57.760	19.083

*N is for 6 observations on 12 subjects.

APPENDIX C

ANALYSES OF VARIANCE

TABLE C1

SUMMARY OF THE SPLIT PLOT ANALYSIS OF VARIANCE FOR THE DEPENDENT

VARIABLES HR AND RPE WITHIN A (12 X 2) X (12) DESIGN

Source	HR			RPE		
	df	MS	F	df	MS	F
Subject (A)	11	1938.58	3.49*	11	26.80	3.56*
Trial (B)	1	6747.35	12.16**	1	506.68	67.23**
A X B (Error A)	11	555.02		11	7.54	
Time (C)	11	3134.06	64.94**	11	50.97	150.08**
B X C	11	69.27	1.44	11	.58	1.69
A X C	121	51.39	1.06	121	.89	2.61**
A X B X C (Error B)	121	48.26		121	.34	

* $p < .05$

** $p < .01$

TABLE C2

SUMMARY OF THE SPLIT PLOT ANALYSIS OF VARIANCE FOR THE DEPENDENT

VARIABLES RQ AND OXP WITHIN A (12 X 2) X (12) DESIGN

Source	RQ			OXP		
	df	MS	F	df	MS	F
Subject (A)	11	.12	1.29	11	.000112	6.27**
Trial (B)	1	.73	7.63*	1	.001213	67.70**
A X B (Error A)	11	.10		11	.000017	
Time (C)	11	.27	27.41**	11	.000038	2.49**
B X C	11	.03	3.13**	11	.000012	0.76
A X C	121	.02	1.46*	121	.000015	0.97
A X B X C (Error B)	121	.01		121	.000016	

* $P < .05$

** $P < .01$

TABLE C3

SUMMARY OF THE SPLIT PLOT ANALYSIS OF VARIANCE FOR THE DEPENDENT VARIABLES

VO_2 1/min. AND VCO_2 1/min. WITHIN A (12 X 2) X (12) DESIGN

	VO_2 1/min.			VCO_2 1/min.		
Source	df	MS	F	df	MS	F
Subject (A)	11	2.73	29.70**	11	3.69	5.27**
Trial (B)	1	15.56	169.21**	1	10.03	14.31**
A X B (Error A)	11	.09		11	.70	
Time (C)	11	1.68	29.78**	11	6.03	63.77**
B X C	11	.07	1.32	11	.07	0.74
A X C	121	.08	1.39*	121	.13	1.42*
A X B X C (Error B)	121	.06		121	.10	

* $P < .05$

** $P < .01$

TABLE C4

SUMMARY OF THE SPLIT PLOT ANALYSIS OF VARIANCE FOR THE DEPENDENT VARIBALES

VO_2 ml/kg/min. AND VCO_2 ml/kg/min. WITHIN A (12 X 2) X (12) DESIGN

	VO_2 ml/kg/min.			VCO_2 ml/kg/min.		
Source	df	MS	F	df	MS	F
Subject (A)	11	202.34	12.07**	11	314.85	2.67
Trial (B)	1	2722.68	162.41**	1	1716.35	14.56**
A X B (Error A)	11	16.77		11	117.90	
Time (C)	11	296.24	29.45**	11	1070.17	64.73**
B X C	11	14.24	1.42	11	13.17	0.80
A X C	121	13.94	1.39*	121	22.85	1.38*
A X B X C (Error B)	121	10.06		121	16.53	

* $P < .05$

** $P < .01$

TABLE C5

SUMMARY OF THE FACTORIAL ANALYSIS OF VARIANCE FOR THE DEPENDENT VARIABLES BW AND Na WITHIN A 12 X 2 DESIGN

	BW			Na		
Source	df	MS	F	df	MS	F
Subject (A)	11	1290.60	78.31**	11	73.59	0.41
Trial (B)	1	3.96	0.24	1	1860.50	10.43**
Error	11	16.48		11	178.32	

* $P < .05$

** $P < .01$

TABLE C6

SUMMARY OF THE FACTORIAL ANALYSIS OF VARIANCE FOR THE DEPENDENT

VARIABLES K^+ AND LA WITHIN A 12 X 2 DESIGN

	K^+			LA		
Source	df	MS	F	df	MS	F
Subject (A)	11	2.88	0.98	11	6231.24	2.57
Trial (B)	1	.85	0.29	1	18348.98	7.56*
Error	11	2.94		11	2425.69	

* $P < .05$

APPENDIX D

STEPWISE REGRESSION ANALYSIS

TABLE D1

SUMMARY OF THE BEST REGRESSION EQUATION FOUND FOR THE PRETEST, TIME 30 SECONDS TO 3 MINUTES (MODEL 1A)

Source	df	Approximate F	P
Regression	4	33.56	.01
HR	1	23.28	.01
OXP	1	12.24	.01
VO_2 1/min.	1	15.05	.01
VCO_2 1/min.	1	25.01	.01
Error	67		
Total	71		

$R = .83$, $R^2 = .68$

Factors included in the model: HR, OXP, RQ, VO_2 1/min., VCO_2 1/min.

TABLE D2

SUMMARY OF THE BEST REGRESSION EQUATION FOUND FOR THE

PRE TEST, TIME 30 SECONDS TO 3 MINUTES (MODEL 2A)

Source	df	Approximate F	P
Regression	4	30.10	.01
HR	1	11.77	.01
VO_2 ml/kg/min.	1	11.40	.01
VCO_2 ml/kg/min.	1	16.91	.01
RQ	1	6.79	.01
Error	67		
Total	71		

$R = .80$, $R^2 = .64$

Factors included in the model: HR, OXP, RQ, VO_2 ml/kg/min., VCO_2 ml/kg/min.

TABLE D3

SUMMARY OF THE BEST REGRESSION EQUATION FOUND FOR THE PRE TEST,

TIME 3 MINUTES 30 SECONDS TO 6 MINUTES (MODEL 1B)

Source	df	Approximate F	P
Regression	4	22.86	.01
HR	1	31.07	.01
VCO_2 1/min.	1	25.23	.01
Na	1	8.44	.01
LA	1	11.29	.01
Error	67		
Total	71		

$R = .76$, $R^2 = .58$

Factors included in the model: HR, OXP, RQ, VO_2 1/min.,
VCO_2 1/min., Na, K^+, LA

TABLE D4

SUMMARY OF THE BEST REGRESSION EQUATION FOUND FOR THE PRE TEST,

TIME 3 MINUTES 30 SECONDS TO 6 MINUTES (MODEL 2B)

Source	df	Approximate F	P
Regression	5	17.38	.01
HR	1	36.14	.01
OXP	1	22.44	.01
RQ	1	7.24	.01
Na	1	8.45	.01
LA	1	5.24	.01
Error	66		
Total	71		

$R = .76$, $R^2 = .58$

Factors included in the model: HR, OXP, VO_2 ml/kg/min.,

VCO_2 ml/kg/min., RQ, Na, K^+, LA.

TABLE D5

SUMMARY OF THE BEST REGRESSION EQUATION FOUND FOR THE

POST TEST, TIME 30 SECONDS TO 3 MINUTES (MODEL 1A)

Source	df	Approximate F	P
Regression	3	25.79	.01
HR	1	7.68	.01
RQ	1	5.19	.05
VCO_2 1/min	1	11.08	.01
Error	68		
Total	71		

$R = .73$, $R^2 = .53$

Factors included in the model: HR, OXP, RQ, VO_2 1/min., VCO_2 1/min.

TABLE D6

SUMMARY OF THE BEST REGRESSION EQUATION FOUND FOR THE

POST TEST, TIME 30 SECONDS TO 3 MINUTES (MODEL 2A)

Source	df		Approximate F	P
Regression	2		34.25	.01
HR		1	6.08	.05
VCO_2 ml/kg/min.		1	31.86	.01
Error	69			
Total	71			

$R = .71$, $R^2 = .50$

Factors included in the Model: HR, OXP, RQ, VO_2 ml/kg/min., VCO_2 ml/kg/min.

TABLE D7

SUMMARY OF THE BEST REGRESSION EQUATION FOR THE POST TEST,

TIME 3 MINUTES 30 SECONDS TO 6 MINUTES (MODEL 1B)

Source	df	Approximate F	P
Regression	6	8.97	.01
HR	1	16.84	.01
OXP	1	12.11	.01
RQ	1	7.14	.01
VCO_2 1/min.	1	10.97	.01
Na	1	6.32	.05
LA	1	9.00	.01
Error	65		
Total	71		

$R = .67$, $R^2 = .45$

Factors included in the model: HR, OXP, RQ, VO_2 1/min., VCO_2 1/min., Na, K^+, LA

TABLE D8

SUMMARY OF THE BEST REGRESSION EQUATION FOUND FOR THE POST TEST,

TIME 3 MINUTES 30 SECONDS TO 6 MINUTES (MODEL 2B)

Source	df	Approximate F	P
Regression	6	10.52	.01
OXP	1	3.63	NS
VO_2 ml/kg/min.	1	11.47	.01
VCO_2 ml/kg/min.	1	8.02	.01
RQ	1	6.00	.05
Na	1	4.08	.05
LA	1	26.04	.01
Error	65		
Total	71		

$R = .70$, $R^2 = .49$

Factors included in the model: HR, OXP, VO_2 ml/kg/min., VCO_2 ml/kg/min., RQ, Na, K^+, LA

APPENDIX E

CALCULATIONS AND LABORATORY PROTOCOL

E1

CALCULATIONS FOR METABOLIC DATA

All calculations performed on the data were handled through a SAS program designed by the author. For the convenience of the reader hand calculations are described below as taken from Consolazio (1963) and Sinning (1975).

First, the STPD factor was calculated for all time intervals during the pre and post test. The formula was as follows:

$$STPD = \frac{273^{o}}{(273^{o} - T_{GAS})} \times \frac{P_{BAR} - P_{H_2O}}{760}$$

Where STPD is the correction factor for standard temperature and pressure dry; T_{GAS} is the gas temperature in degrees Centigrade; P_{BAR} is the atmospheric pressure in mm Hg (barometer reading in inches then converted to mm) and P_{H_2O} is the water vapor pressure in mm Hg (values for P_{H_2O} can be found in Sinning (1975, p. 95).

$VE_{(ATPS)}$ was then computed by using the formula

$$VE_{(ATPS)} = VI_{(ATPS)} \div \frac{N}{79.04}$$

Where $VI_{(ATPS)}$ is the volume of inspired gas at atmospheric temperature and pressure saturated and N is the percent of nitrogen in the expired air.

Then, $VE_{(ATPS)}$ was converted to $VE_{(STPD)}$ by the formula:

$$VE_{(STPD)} = VE_{(ATPS)} \times STPD$$

VE_{O_2} was then computed as follows:

$$VE_{O_2} = VE_{(STPD)} \times \frac{FE_{O_2}}{100}$$

Where FE_{O_2} is the percent concentration of O in expired air and $VE_{(STPD)}$ is the volume of expired gas at standard temperature and pressure dry.

$VI_{(STPD)}$ was computed:

$$VI_{(STPD)} = VI_{(ATPS)} \times STPD$$

Where $VI_{(ATPS)}$ is the volume of inspired gas at atmospheric temperature and pressure saturated.

Percent of N_2 in expired air (FE_{N_2}) was calculated by the formula:

$$FE_{N_2} = 100 - (FE_{O_2} - FE_{CO_2})$$

Where FE_{O_2} is the percent of O_2 in expired air and FE_{CO_2} is the percent of CO_2 in expired air.

Since heavier people tend to have larger O_2 consumption, VO_2 l/min. was then converted to VO_2 ml/kg/min. where:

$$VO_2 \text{ ml/kg/min.} = \frac{VO_2 \text{ l/min.} \times 1000 \text{ ml/liter}}{\text{subject's weight (kg)}}$$

Carbon dioxide production was then calculated (l/min. and ml/kg/min.) by the use of the following formulas:

$$V_{CO_2(STPD)} = VE_{CO_2(STPD)} - VI_{CO_2(STPD)}$$

Where $VE_{CO_2(STPD)}$ is the volume of expired CO_2 at STPD and $VI_{CO_2(STPD)}$ is the volume of inspired CO_2 at STPD.

$$V_{CO_2} \text{ l/min.} = \frac{V_{CO_2(STPD)}}{\text{collection time}}$$

$$V_{CO_2} \text{ ml/kg/min.} = \frac{V_{CO_2} \text{ l/min. X 1000 ml/liter}}{\text{subject's weight (kg)}}$$

RQ was calculated by utilizing the following formula:

$$RQ = \frac{CO_2\% - .03}{N \text{ X } .265 - O_2\%}$$

Where $CO_2\%$ is the percent of CO_2 in expired air, N is the percent of nitrogen in expired air and O_2 is the percent of O_2 in expired air.

OXP was calculated by the following formula:

$$OXP = \frac{VO_2 \text{ l/min.}}{HR}$$

E2

Blood Chemistry

The analysis for determination of sodium and potassium was conducted at the Department of Animal Sciences, Louisiana State University, Baton Rouge, Louisiana. All samples were delivered in 4ml glass vacutainers to the Pathology Laboratory where lab technicians conducted the analysis.

For the determination of lactic acid, initial preparations were conducted at the Department of Animal Sciences by the author. Centrifuge tubes containing the deproteinized blood were used for the lactate analysis procedure. All samples were placed in a centrifuge and spun for at least 5 min. at 3000 rpms. After centrifuging was completed the supernatant was removed carefully and placed in a 4 cc glass vial. The substrate was then discarded.

The supernatant specimens were taken to the School of Veterinary Medicine Pathology Laboratory where each sample was incubated in a constant temperature water bath at 30^{o} Centigrade for 5 min. Upon completion of the pre-incubation period, a 5.0 ml pipette was used to dispense 2.9 ml of prepared reagent into a clean, dry cuvet with a 1 cm light path. Each cuvet was then placed in a Beckman Spectrophotometer set at 340 nm using a distilled water as a blank. An initial absorbence measurement was recorded from the spectrophotometer. After completion of the initial absorbence measurements, .050 ml of the supernatant was added to the cuvets and mixed quickly by gentle inversion with a square of Parafilm over the mouth of the cuvet. All samples were then returned to the constant temperature water bath for 15 min. Upon completion of the incubation period all cuvets were remeasured for absorbence changes in the spectrophotometer. The concentration of lactic acid present in the blood was computed utilizing the formula $A = [A_{15} - (A_0 \times 0.967)] \times 1.97$ where A = the change in absorbence; A_{15} = the absorbence at the end of the 15 min. period; A_0 = the initial absorbence; .967 = a constant to correct a change in volume due to the additional .050 ml of supernatant; and 1.97 = the dilution factor for .050 ml of supernatant. A is then multiplied by 131 in order to present the lactic acid concentration in mg/dl.

APPENDIX F

F1

Alternative Statistical Analysis

Because inherent problems possibly exist in the stepwise regression analysis an alternative statistical interpretation is offered. In the original analysis of the data, the 6 min. work bouts were divided into two, 3 min. periods, one representing an early period (30 sec. to 3 min.) and one representing a late period (3 min., 30 sec. to 6 min.). Due to the arrangement of the data, possible correlations might exist between the data points of individual subjects as well as a correlation existing between the variables and time. Therefore, the data were arranged so that regressions were computed at each 30 sec. interval. This arrangement of the data was an attempt to eliminate the above correlations. However, it should be noted that by arranging the data in this manner the variance was greatly reduced between data points. The results of the alternative analysis are presented in Tables F2 through F9. The stepwise multiple regressions presented in Appendix F contain a total of 11 df (N - 1 df for subjects).

TABLE F2

SUMMARY OF THE SIGNIFICANT REGRESSION EQUATIONS FOUND FOR THE PRE TEST

AT EACH 30 SECOND INTERVAL FOR THE FIRST 3 MINUTES (MODEL 1A)

	30		1:00		1:30		2:00		2:30		3:00	
Variable	Order	F	Order	F	Order	F	Order	F	Order	F	Order	F
HR							1	18.43**	1	12.20**	1	12.72**
OXP							2	17.14**				
RQ											2	4.00NS
VO_2 l/min.							3	17.50**	2	20.17**	3	5.10NS
VCO_2 l/min.									3	30.48**	4	5.63*
R								.85		.92		.82
R^2								.72		.85		.67

* P $<$.05

** P $<$.01

Factors included in the Model: HR, OXP, RQ, VO_2 l/min., VCO_2 l/min.

TABLE F3

SUMMARY OF THE SIGNIFICANT REGRESSION EQUATIONS FOUND FOR THE PRE TEST

AT EACH 30 SECOND INTERVAL FOR THE FIRST 3 MINUTES (MODEL 2A)

	30		1:00		1:30		2:00		2:30		3:00	
Variable	Order	F	Order	F	Order	F	Order	F	Order	F	Order	F
HR												
OXP									1	10.64**		
RQ												
VO_2 ml/kg/min.									2	37.92**		
VCO_2 ml/kg/min.												
R										.91		
R^2										.82		

* $P < .05$

** $P < .01$

Factors included in the model: HR, OXP, RQ, VO_2 ml/kg/min., VCO_2 ml/kg/min.

TABLE F4

SUMMARY OF THE SIGNIFICANT REGRESSION EQUATIONS FOUND FOR THE PRE TEST AT EACH 30 SECOND INTERVAL FOR THE LAST 3 MINUTES (MODEL 1B)

Variable	3:30		4:00		4:30		5:00		5:30		6:00	
	Order	F	Order m	F	Order	F	Order	F	Order	F	Order	F
HR									1	11.24**	1	10.34*
OXP					1	5.44*	1	6.26*			2	7.82*
RQ												
VO_2 l/min.											3	7.06*
VCO_2 l/min.									2	6.95*		
Na					2	11.52**	2	11.47**			4	4.67NS
K^+					3	4.97*	3	4.66NS				
LA									3	3.22NS		
R						.79		.80		.87		.88
R^2						.62		.64		.76		.77

* $P < .05$
** $P < .01$

Factors included in the model: HR, OXP, RQ, VO_2 l/min., VCO_2 l/min., Na, K^+, LA

TABLE F5

SUMMARY OF THE SIGNIFICANT REGRESSION EQUATIONS FOUND FOR THE PRE TEST

AT EACH 30 SECOND INTERVAL FOR THE LAST 3 MINUTES (MODEL 2B)

	3:30		4:00		4:30		5:00		5:30		6:00	
Variable	Order	F	Order	F	Order	F	Order	F	Order	F	Order	F
HR	1	13.58**							1	17.37**	1	13.66**
RQ	4	26.55**							4	10.40**	5	4.37NS
OXP	2	21.42**							2	9.68**	2	5.49NS
VO_2 ml/kg/min.											3	8.14*
VCO_2 ml/kg/min.	3	13.30**							3	4.18NS	4	5.47*
Na	5	13.61**									6	4.16NS
K^+												
LA												
R		.92								.92		.93
R^2		.84								.84		.86

* $P < .05$

** $P < .01$

Factors included in the model: HR, RQ, OXP, VO_2 ml/kg/min., VCO_2 ml/kg/min., Na, K^+, LA

TABLE F6

SUMMARY OF THE SIGNIFICANT REGRESSION EQUATIONS FOUND FOR THE POST TEST AT EACH 30 SECOND INTERVAL FOR THE FIRST 3 MINUTES (MODEL 1A)

Variable	30		1:00		1:30		2:00		2:30		3:00	
	Order	F	Order	F	Order	F	Order	F	Order	F	Order	F
HR												
OXP					1	3.86NS						
RQ							1	6.23*			1	8.39*
VO_2 l/min.												
VCO_2 l/min.			1	15.37**	2	11.12**	2.	5.23*				
R				.78		.84		.74				.68
R^2				.61		.70		.51				.46

* $P < .05$
** $P < .01$

Factors included in the model: HR, OXP, RQ, VO_2 l/min., VCO_2 l/min.

TABLE F7

SUMMARY OF THE SIGNIFICANT REGRESSION EQUATIONS FOUND FOR THE POST TEST AT EACH

30 SECOND INTERVAL FOR THE FIRST 3 MINUTES (MODEL 2A)

Variable	30		1:00		1:30		2:00		2:30		3:00	
	Order	F	Order	F	Order	F	Order	F	Order	F	Order	F
HR			1	8.88*	1	7.19*						
OXP			2	10.55**								
RQ			3	10.24**	2	6.33*						
VO_2 ml/kg/min.												
VCO_2 ml/kg/min.												
R				.84		.79						
R^2				.70		.62						

* $P < .05$
** $P < .01$

Factors included in the model: HR, OXP, RQ, VO_2 ml/kg/min., VCO_2 ml/kg/min.

TABLE F8

SUMMARY OF THE SIGNIFICANT REGRESSION EQUATION FOUND FOR THE POST TEST AT EACH 30 SECOND INTERVAL FOR THE LAST 3 MINUTES (MODEL 1B)

	3:30		4:00		4:30		5:00		5:30		6:00	
Variable	Order	F	Order	F	Order	F	Order	F	Order	F	Order	F
HR											1	6.47*
OXP											2	5.70*
RQ												
VO_2 l/min.											3	5.40*
VCO_2 l/min.												
NA											4	2.87NS
K^+												
LA												
R												.84
R^2												.70

* $P < .05$
** $P < .01$

Factors included in the model: HR, OXP, RQ, VO_2 l/min., VCO_2 l/min., NA, K^+, LA

TABLE F9

SUMMARY OF THE SIGNIFICANT REGRESSION EQUATIONS FOUND FOR THE POST TEST AT EACH

30 SECOND INTERVAL FOR THE LAST 3 MINUTES (MODEL 2B)

	3:30		4:00		4:30		5:00		5:30		6:00	
Variable	Order	F	Order	F	Order	F	Order	F	Order	F	Order	F
HR												
OXP												
RQ							3	10.77**				
VO_2 ml/kg/min.							1	12.29**			1	7.68*
VCO_2 ml/kg/min.							2	11.27**				
NA												
K^+												
LA							4	12.58**			2	5.56*
R								.93				.77
R^2								.86				.60

* $P < .05$
** $P < .01$

Factors included in the model: HR, OXP, RQ, VO_2 ml/kg/min, VCO_2 ml/kg/min., NA, K^+, LA

VITA

The author was born in Port Arthur, Texas on October 5, 1951. He attended Thomas Jefferson High School in Port Arthur and graduated in 1970. He attended Lamar University, Beaumont, Texas, graduating in 1973 with a Bachelor of Science degree in Health and Physical Education.

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EXAMINATION AND THESIS REPORT

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Major Field: Health, Physical and Recreation Education

Title of Thesis: The Influence of Various Physiological Responses on Ratings of Perceived Exertion Before and After Training

Approved:

Jack K Nelson
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Date of Examination:

July 20, 1978